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Monographs on Medicinal Plants along Ganga River
Ricinus communis L.

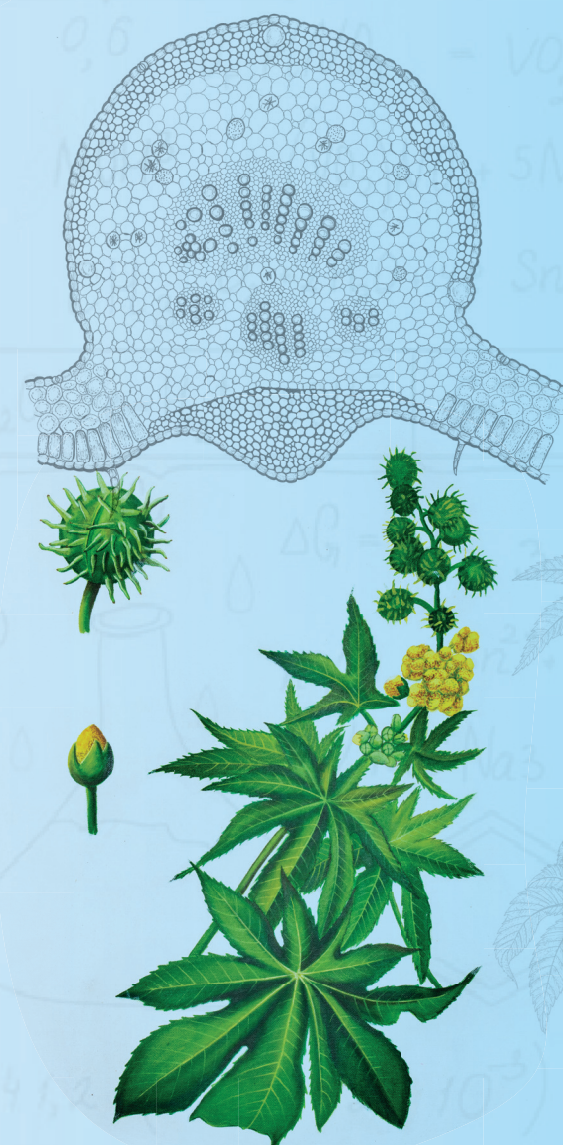


Monographs on Medicinal Plants
along Ganga River

Ricinus communis L.

Focusing on
Botanical, Phytochemical, Scientific Validation and
Insilico Analysis Including Medicinal Importance
and Soil Properties

Volume 7



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Botanical, Phytochemical, Scientific validation and Insilico
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Volume 07

Sponsored by



National Mission for Clean Ganga (NMCG),
Department of Water Resources, River
Development & Ganga Rejuvenation,
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with their Conservation and Economic Development of the Region via Skill Development Programs" of The
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Implemented by Patanjali Organic Research Institute Pvt. Ltd. (PORI)
Food & Herbal Park, Village-Padartha, Laksar Road, Haridwar-249407, Uttarakhand (India)



ABOUT THE EDITOR

Dr. Acharya Balkrishna, Co-founder of Patanjali Organic Research Institute, is a highly ascetic entrepreneur with a diverse personality who is a specialist in Yoga, Ayurveda, Sanskrit language, Indian sacred books, and the Vedas. Dr. Balkrishna has become a significant source of inspiration for Traditional Medicinal Practitioners and a globally recognized celebrity after dedicating his life to the resurrection of ancient healing and living practices. His maverick leadership as Co-Founder & Managing Director of Patanjali Ayurved Limited, along with overseeing Patanjali Food and Herbal Park and Divya Pharmacy, has propelled Ayurveda into a global business phenomenon with a massive following. Additionally, he has been decorated with prestigious awards such as 'Ayurveda Expert', 'Manav Ratan', 'Bharat Gaurav', 'Indian of the Year', 'Ten Versatile and Dynamic Young Men of India', 'Bheeshma Pusaka', 'Lokmanya Tilak', and 'Transformational Business Leader' for his exceptional knowledge, passion, and service to mankind. According to a study published by Stanford University in the USA and Elsevier in Europe, Dr. Balkrishna has been recognized among the top 2% of scientists worldwide for his research on Ayurveda and Yoga.

With his early age passion for plants, he has become the most renowned & respected herbal specialist for health and nutrition. For the research of novel herbal medication formulations, he explored four rare plants: 'Sanjeevani', 'Somlata', 'Swarnakshiri', 'Swarnadraka', and 'Astavavarga plants'. He has taken many initiatives for Biodiversity conservation, presently working for the establishment of Patanjali Herbal Garden & herbarium, working on the compilation of a unique multivoluminous project i.e., 'World Herbal Encyclopaedia', containing the descriptions of ~50,000 medicinal plant species with the largest collection of plant paintings and drawings. This is being done to strengthen traditional medicine systems of the world. Additionally, Dr. Balkrishna has made significant contributions to the socio-economic development of tribal communities and the upliftment of rural communities with FPOs, CLFs, and SHGs. Furthermore, his endeavors have been directed towards exploring and conserving floral diversity, phytochemical and insilico analysis, investigating soil geochemistry, understanding complex plant-microbe relationships, and monitoring water quality from Gomukh to Gangasagar.

He has published more than 400 research articles in national and international journals received around 20 patents and authored more than 200 books on Yoga, Ayurveda, Agriculture, Herbal Medicine, and Information Technology and edited more than 40 unpublished ancient Ayurveda manuscripts. With

the vision of ensuring universal health for the last two decades, more than 1.5 million patients with several persistent, chronic, and non-communicable diseases have been effectively treated. He established Patanjali Ayurved College and the University of Patanjali with the humanitarian goal of assisting youngsters in achieving their goals and serving the country. Additionally, he has been involved in various government and non-government initiatives. He is also a key proponent of agricultural transformation through organic practices, working to boost agricultural productivity, increase farmer income, and ensure equitable access to a safe, affordable, and nutritious diet year-round. Apart from this, Dr. Balkrishna is actively participating in driving agricultural transformation through the 'Patanjali Farmer Samridhi Programme' by well-trained staff and around one lakh trainers. His generous personality is also reflected through his actions like helping the nation with emergency needs like post-disaster needs assessment, providing free shelter, food, and education to orphan children, and free OPD services at Patanjali Yogpeeth. With his humanitarian attitude, Dr. Balkrishna continues his phenomenal journey of making world records, uplifting mankind through medicine & lifestyle improvement, reviving sustainable agriculture, and preserving nature's gifts in the form of literature and a sustainable living approach.





Vision of Honourable Prime Minister

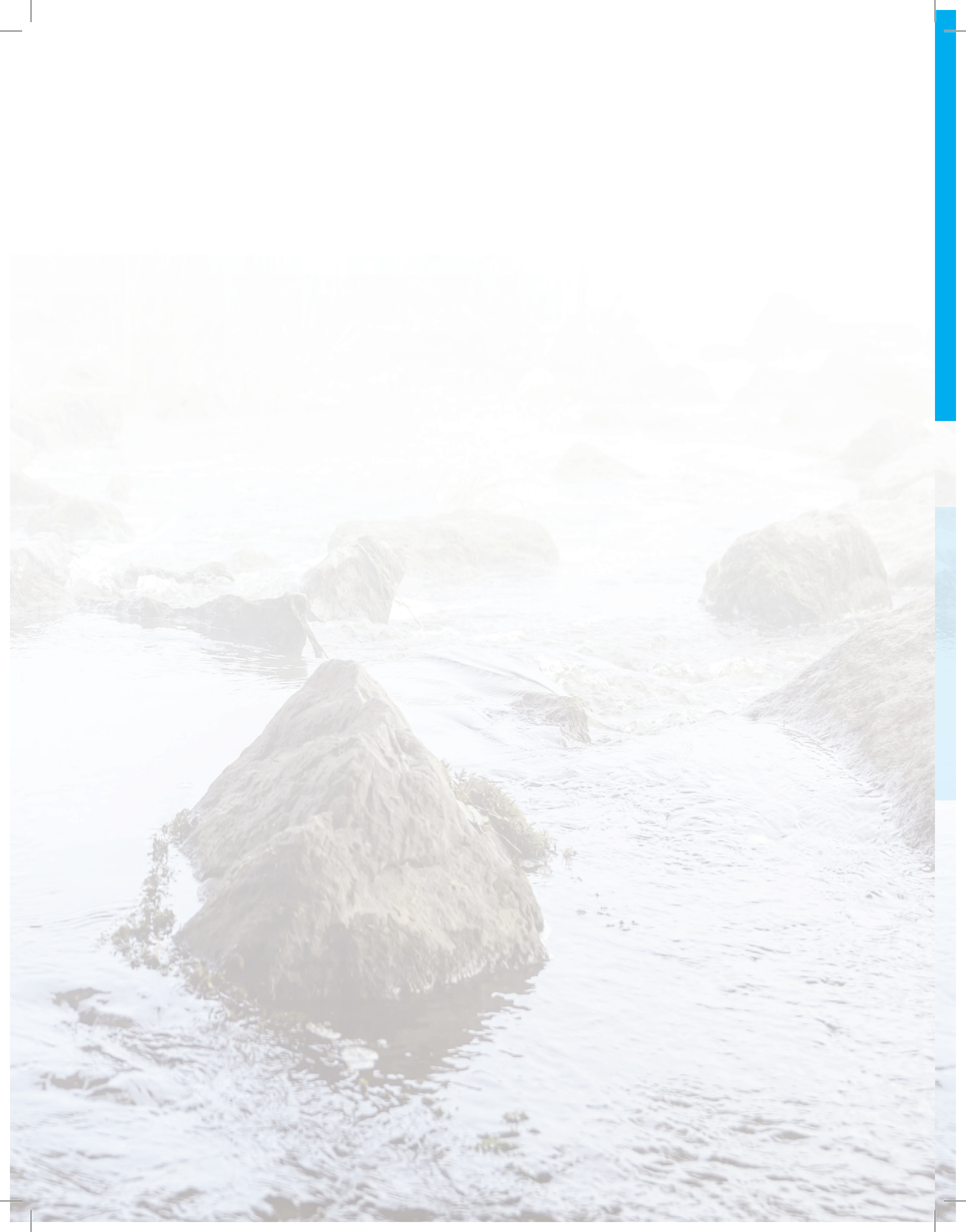
Shri Narendra Modi on Medicinal Plants



1. India's rich biodiversity of medicinal plants can provide affordable healthcare solutions.
2. Medicinal plants are nature's gift to humanity; we must protect and utilize them wisely.
3. Let us revive and promote the use of medicinal plants in everyday life.
4. India's biodiversity of medicinal plants is a treasure trove waiting to be explored.
5. Medicinal plants have been an integral part of our cultural heritage, offering natural remedies for various ailments.
6. The knowledge embedded in our traditional systems like Ayurveda and the use of medicinal plants can address global health challenges sustainably.
7. We must promote research and innovation in harnessing the potential of medicinal plants for healthcare and economic development.



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Vision of Union Minister for Jal Shakti

Shri Chandrakant Raghunath Patil

“

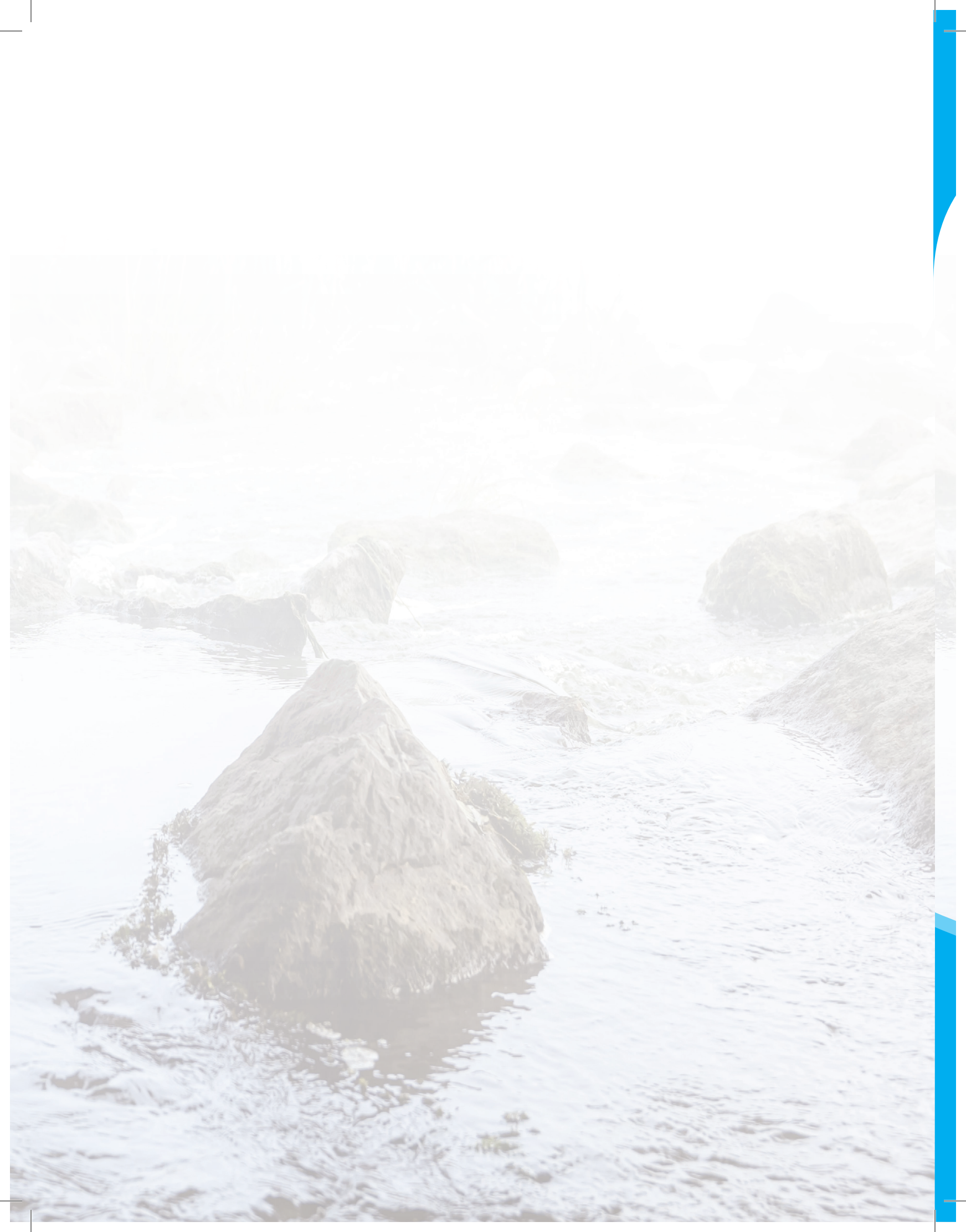
1. We will understand the importance of water, conserve it and ensure rich water resources for future generations.
2. Conservation and enhancement of water resources of our country is a sacred goal. I will work with my dedication and devotion to achieve this.
3. Proper access to water is a strong step towards women's empowerment.
4. Jal Shakti is Nari Shakti, as women are the most affected by water scarcity due to their household responsibilities in rural India.

”

<https://pib.gov.in/PressReleaseDetail.aspx?PRID=2024324>

<https://www.newsonair.gov.in/c-r-patil-emphasizes-water-access-as-essential-for-womens-empowerment-at-catch-the-rain-2024-workshop-in-delhi/>

<https://www.indiatvnews.com/gujarat/will-transform-jal-shakti-into-rashtra-shakti-cabinet-jal-shakti-minister-c-r-patil-after-portfolio-appointment-pm-modi-2024-06-10-936272>



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Uttar Pradesh Forest Department & Biodiversity Board

Bihar Forest Department & Biodiversity Board

Jharkhand Forest Department & Biodiversity Board

West Bengal Forest Department & Biodiversity Board

Ganga Task Force (GTF)

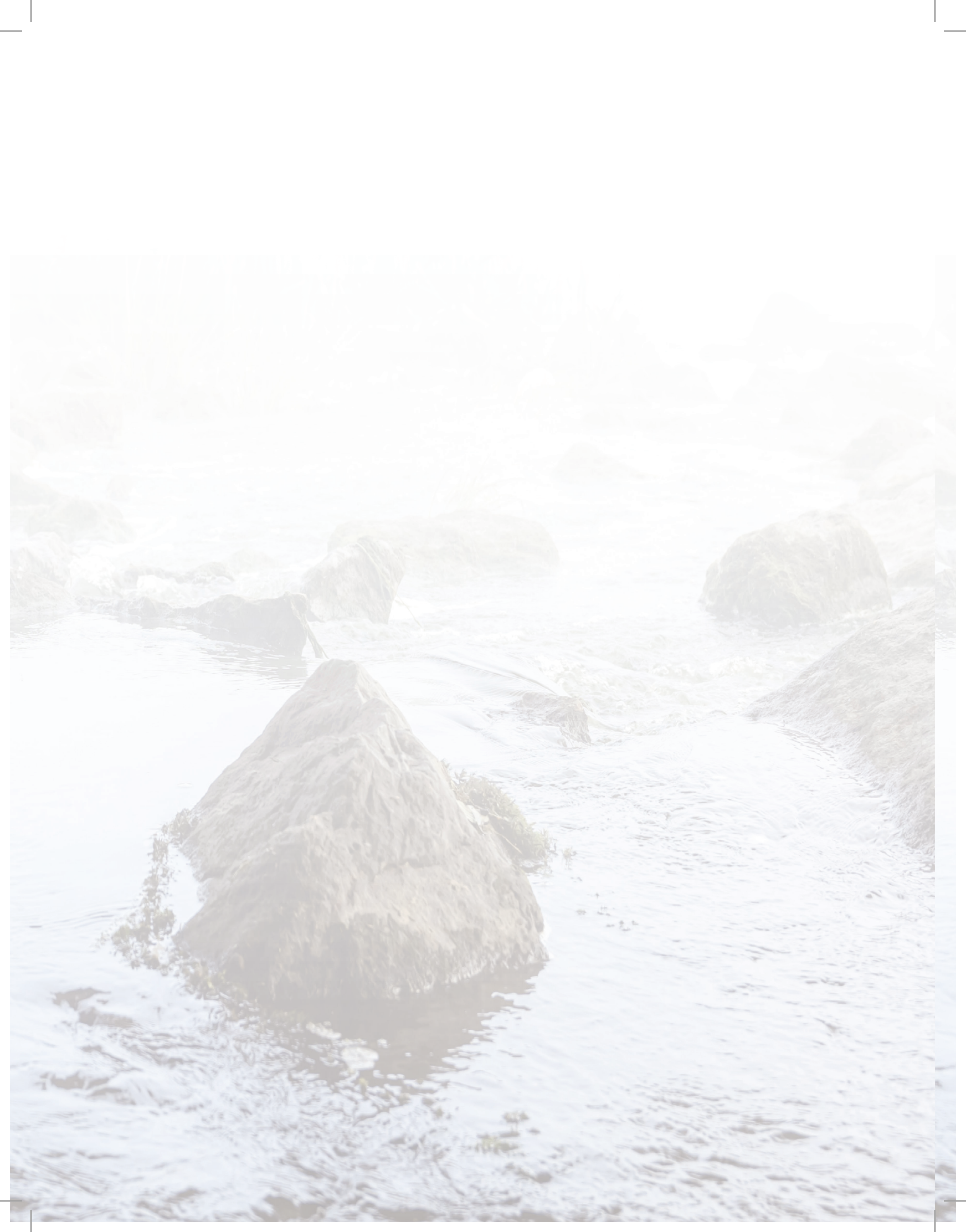


Table of CONTENTS

Classical Ayurvedic Insight 1

➤ <i>Ricinus communis</i> L.	3
♦ Distribution	3
♦ Botanical Description	4
♦ Plant Anatomy	5
♦ Microscopic Characters	7
♦ Medicinal Uses	7
♦ References	20
♦ Abbreviation	21

01

Plant Exploration and Botanical Study 23

INTRODUCTION	25
➤ Genus <i>Ricinus</i> L.	28
♦ Etymology	28
♦ Species	28
➤ <i>Ricinus communis</i> L.	29
♦ Classification	29
♦ Common Names	31
♦ Global Distribution	31
♦ Distribution in India	32
♦ Ethnobotany and Traditional Uses	32
♦ Phytochemical Constituents	33
♦ Selection of the Sites and Characteristics Studied	34
♦ Local Occurrence	35
♦ Taxonomic Treatment	35
♦ Synonyms	35
• Homotypic Synonyms	35
• Heterotypic Synonyms	35
• Ecogeographical Grouping	50

♦ Botanical Description	50
♦ Chromosome Number	52
♦ Anatomical Features	52
• Structure of the Leaf	52
• Structure of the Stem	53
• Structure of the Root	53
➤ References	54

02

Bibliometric Analysis

Bibliometric Analysis	57
INTRODUCTION	59
➤ Insights with Data Source and Tools	61
➤ Comprehensive Data-driven Insights	62
♦ Temporal Evolution and Growth Analysis	62
♦ Citation Analysis	63
♦ Country-wise Publication Analysis	65
♦ Most Prominent Authors	66
♦ Highly Cited Articles	66
♦ Most Active Journals	68
♦ Top Productive Organizations	70
♦ Top Fields of Study	71
➤ Research Collaboration Networks	72
♦ Authors' Collaboration Network	72
♦ Journal-wise Collaboration Network	72
♦ Organizational Collaborative Network	74
♦ Country-wise Collaboration Network	75
➤ Conclusion	76
➤ References	76

03

Soil Properties

Soil Properties	79
INTRODUCTION	81
➤ Sampling Sites	84
➤ Soil Analysis	87

♦ Physicochemical Analysis of Soil	87
• Total Moisture Content (%)	87
• Bulk Density	87
• pH	88
• Electrical Conductivity	89
• Organic Carbon	90
• Available Nitrogen	91
• Available Phosphorous	92
• Available Potassium	94
• Available Sulphur	95
• Heavy Metal	97
• Micronutrient	97
♦ Correlation Studies and Statistical Analysis	99
➤ Results and Discussion	100
♦ Physicochemical Characterization of Soil	100
♦ Total and Differential Bacterial Count from Rhizosphere	110
♦ Correlation Coefficient Matrix	112
➤ Conclusion	113
➤ References	116

04

Traditional and Ethnomedicinal Applications 119

INTRODUCTION	121
➤ Traditional and Ayurvedic Benefits	123
➤ Therapeutic Potential	138
➤ Ethnomedicinal and Folk treatments along the Ganga Basin of India	143
➤ Conclusion and Future Perspectives	145
➤ References	146

05

Phytochemical Analysis 153

INTRODUCTION	155
➤ Sampling Sites	157
➤ Phytochemical Analysis	157
♦ Determination of Tannin Content	157
♦ Determination of Saponin Content	158

♦ Determination of Total Polyphenol Content.....	158
♦ Determination of Total Flavonoid Content.....	158
➤ HPTLC Fingerprinting.....	158
♦ Sample Preparation.....	159
➤ Methodology and Analytical Conditions.....	159
➤ High-Performance Liquid Chromatography (HPLC).....	159
♦ Sample and Standard Preparation.....	159
♦ Analytical and Instrumentation Condition.....	160
➤ Identification of Compounds by Ultra Performance Liquid Chromatography Quadrupole Time-of-Flight Mass Spectrometry (UPLC/MS-QToF).....	160
♦ Sample Preparation.....	160
♦ Analytical and Instrumentation Conditions.....	160
➤ Results and Discussion.....	162
♦ Phytochemical Analysis.....	162
♦ HPTLC Fingerprint Analysis.....	163
♦ HPLC Analysis.....	165
♦ UPLC/MS-QToF Analysis.....	167
➤ Conclusion.....	170
➤ References.....	171

06

In silico Analysis Against Gastric Cancer

In silico Analysis Against Gastric Cancer.....	173
INTRODUCTION.....	175
➤ Etiology of Gastric Cancer.....	178
➤ Reported Therapeutic Use.....	178
➤ Materials and Methods.....	180
♦ Protein Structure Retrieval and Preparation.....	180
♦ Phytochemical Library Preparation.....	181
♦ Rule of Five (R05).....	181
♦ Molecular Docking.....	181
♦ Bioavailability Radar and Bioactivity Score.....	181
♦ <i>In silico</i> ADMET analysis.....	182
♦ Molecular Dynamics Simulation.....	182
➤ Results and Discussion.....	183
♦ Preliminary Screening of Drug likeness.....	183

♦ Molecular Docking Analysis	186
♦ Bioavailability Radar and Bioactivity Score	188
♦ <i>In Silico</i> ADMET Analysis	190
♦ Molecular Dynamics Simulations	191
• RMSD of ACOT4-2,7-diphenyl-1,6-dioxypyridazino [4,5:2',3']pyrrolo [4',5'-d] pyridazine complex	192
• RMSF of ACOT4-2,7-diphenyl-1,6-dioxypyridazino [4,5:2',3']pyrrolo [4',5'-d] pyridazine complex	192
• Protein-ligand Contacts	193
• Ligand Torsion Analysis	194
➤ Conclusion	195
➤ References	196

07

Reported Pharmacological Profile 201

➤ Pre-Clinical Study	203
♦ Analgesic Activity	203

INTRODUCTION 203

♦ Anti-asthmatic Activity	205
♦ Anti-convulsant Activity	205
♦ Anti-diabetic Activity	205
♦ Anti-fertility Activity	205
♦ Anti-inflammatory Activity	205
♦ Anti-leishmanial Activity	206
♦ Anti-malarial Activity	206
♦ Anti-microbial Activity	206
♦ Antioxidant Activity	207
♦ Anti-parasitic Activity	208
♦ Anti-tumor Activity	208
♦ Contraceptive Activity	208
♦ Cytotoxicity	209
♦ Effects on Reproductive System	209
♦ Enzyme Inhibitory Activity	209
♦ Hemagglutinating Activity	209
♦ Hepatoprotective Activity	210
♦ Mutagenicity	210
♦ Anti-spermatogenic Activity	210

➤ Toxicological Study	210
➤ Summary And Future Outlook	211
➤ References	211





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Rajeev Kumar Mital, IAS
DIRECTOR GENERAL
NATIONAL MISSION FOR CLEAN GANGA



सत्यमेव जयते
75
आज़ादी का
अमृत महोत्सव

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION



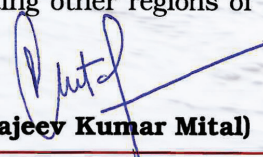
MESSAGE

The Ganga, a river deeply revered in our culture, is both a source of spiritual inspiration and home to diverse ecosystems, including riparian buffers along its banks that connect terrestrial and aquatic systems. These buffers play a crucial role in supporting amphibious life, stabilizing the riverbanks, and maintaining ecosystem services. Therefore, under the "Aviral Ganga" approach for biodiversity conservation and "Arth Ganga" for enhancing livelihoods, a project on floral diversity has been initiated through Namami Gange Mission – II, in collaboration with Patanjali Organic Research Institute (PORI), Haridwar, Uttarakhand.

The project "Scientific Exploration of Floral Diversity Near the Ganga Riverbanks for Ethnobotanical Purposes along with their Conservation and Economic Development of the Region via Skill Development Programs" aims to provide valuable scientific insights into the region's ethnobotanical wealth while promoting sustainable conservation practices. The 18-month study, conducted from Gaumukh to Gangasagar along the Ganga banks, reveals the floral profile, ethno medicinal aspects, applications, livelihood perspectives, and the role of biodiversity in ecosystem resilience, highlighting the symbiotic relationship between conservation and socio-economic development. Findings presented through publications, including project reports, monographs, exploration of ethno medicinal plants, and plant wealth along river Ganga India, will benefit stakeholders, including local communities' well-being.

It gives me immense pleasure to extend my appreciation to the entire team for successfully executing the project, which advances our understanding of the unique floral diversity along the Ganga and its role in ethnobotanical purposes, conservation, and integrating science with local knowledge. The project's focus on environmental stewardship and skill enhancement for sustainable livelihoods is commendable.

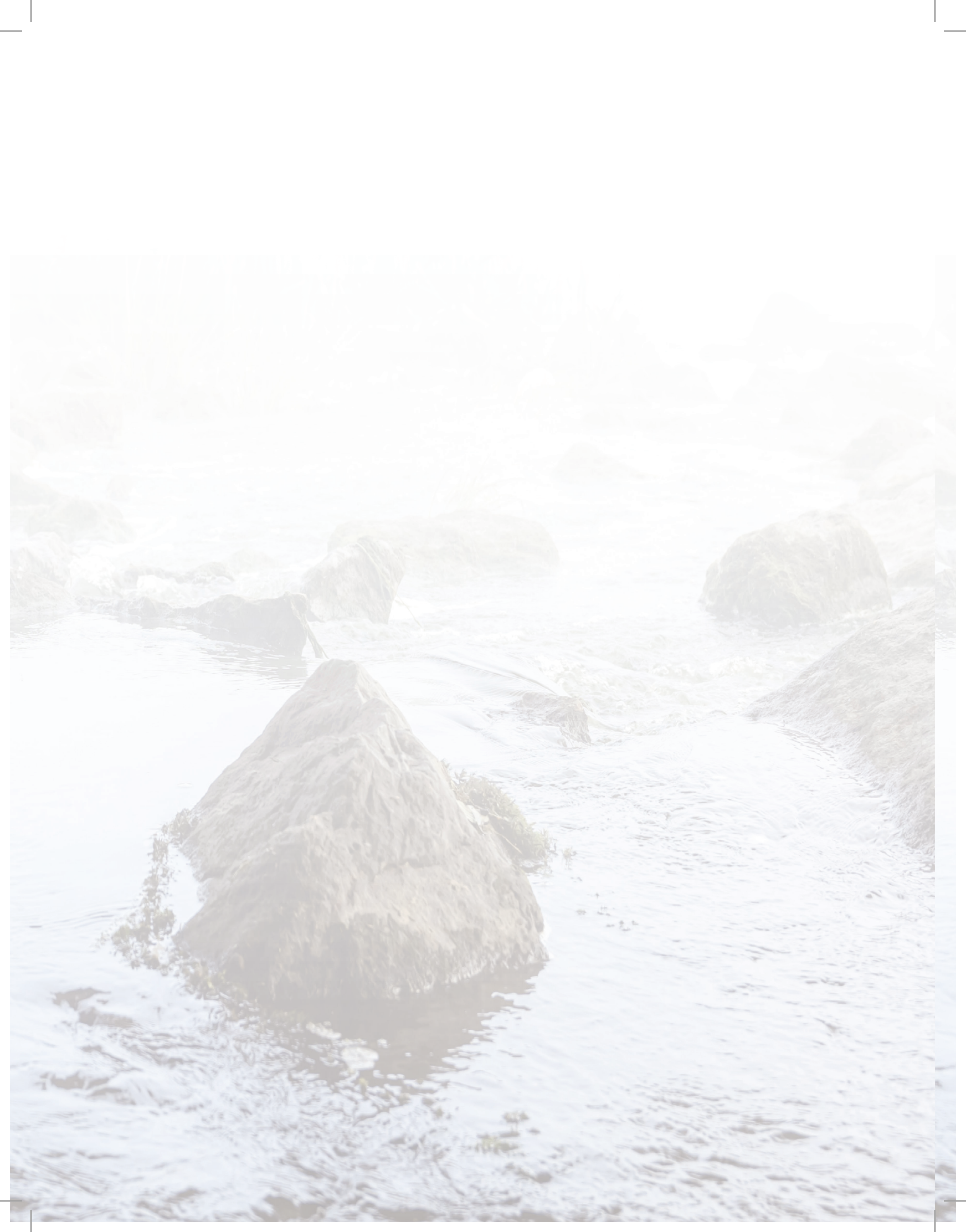
This excellent work documenting the floral diversity along the banks may pave the way for the rejuvenation of the Ganga and set a precedent for biodiversity conservation and socio-economic improvement, potentially benefiting other regions of India as well.


(Rajeev Kumar Mital)



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FOREWORD

*I*n the timeless flow of the sacred Ganga River, lies a profound treasure trove of nature's healing bounty. As we embark on this journey through the pages of this book on Medicinal Plants along the Ganga River, we are reminded of the ancient wisdom that has sustained our civilization for millennia. The Ganga, revered not only for its spiritual significance but also for its ecological richness, nurtures a diverse array of medicinal plants. The plant, meticulously documented in this comprehensive work, are not merely botanical specimen but living reservoir of phytochemicals that hold immense therapeutic potential.

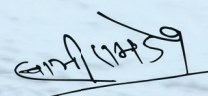
The authors have meticulously documented the plant exploration and botanical study, soil properties analysis, phytochemical analysis, and insilico analysis of the plants found in this region. Their dedication and deep respect for nature's wisdom are evident throughout the pages, making this monograph an invaluable resource for all who seek to deepen their understanding of the healing potential found in the lap of the Himalayas.

Moreover, the inclusion of phytochemical and bioinformatic aspects adds a modern scientific perspective to this ancient knowledge. By unraveling the chemical constituents and molecular mechanisms behind the therapeutic effects, this monograph bridges the gap between traditional wisdom and contemporary scientific advancements, paving the way for evidence-based herbal medicine.

I extend my heartfelt appreciation to Acharya Balkrishna Ji and his devoted team of expert scientists for their unwavering commitment for preserving and disseminating the wisdom of the Medicinal Plants along Ganga River. Their work not only contributes to the scientific community but also instills a deep reverence for nature and its intricate web of life.

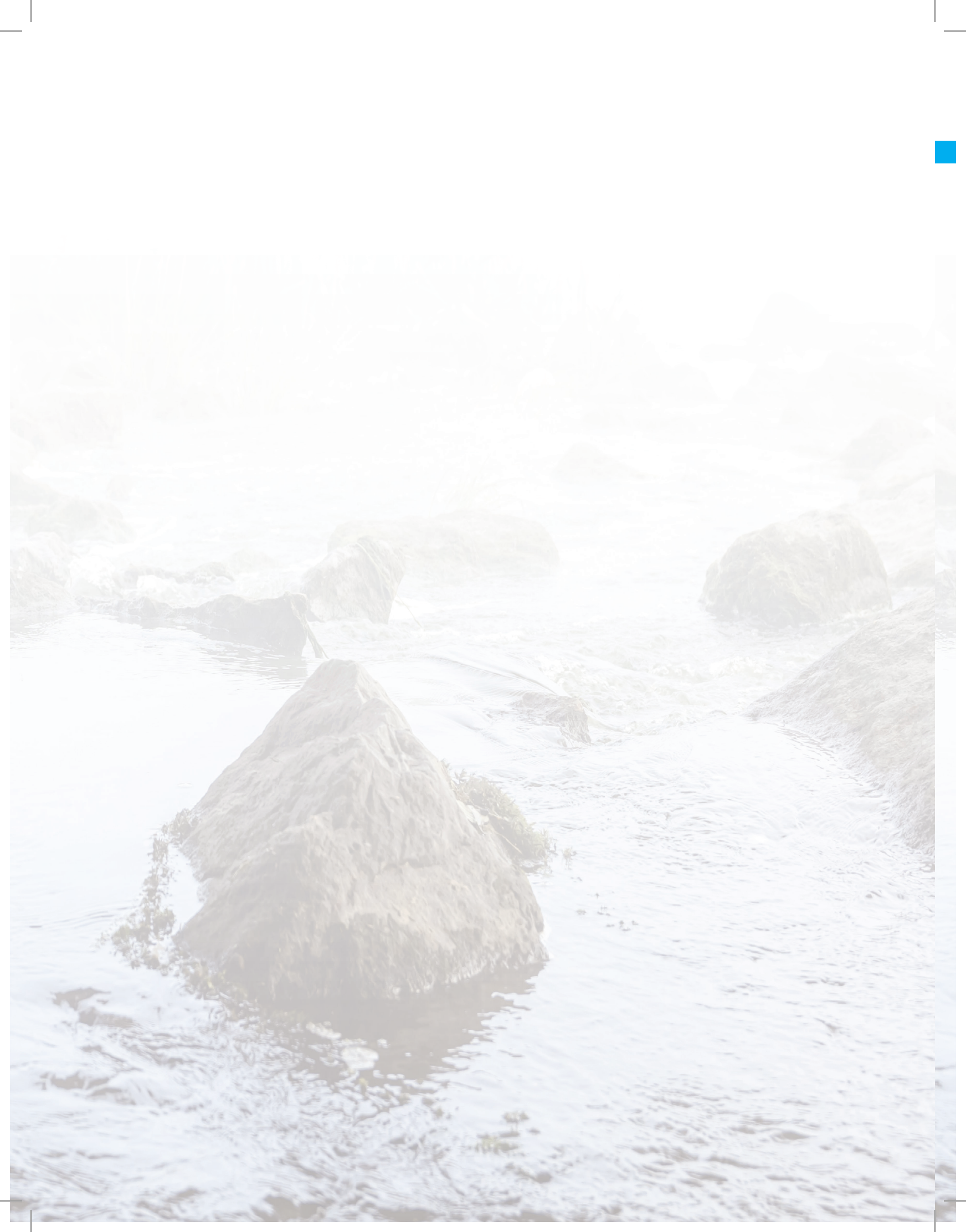
May this monograph serve as a guiding light for researchers, practitioners, and enthusiasts alike, illuminating the path towards a deeper appreciation of nature's pharmacy along the revered Ganga River.

With heartfelt gratitude and blessings,



- Swami Ramdev





PREFACE

The Ganga River, revered as the lifeblood of India, flows through the heart of the country, nourishing not only the land but also the spirit of the people. It is not just a geographical entity; it is a symbol of life, purity, and sustenance. From its origin in the pristine glaciers of Uttarakhand to its expansive delta in West Bengal, the Ganga traverses diverse landscapes, each rich in its own unique flora and fauna. For centuries, it has supported a wide variety of ecosystems, each harbouring plant species that are integral to the ecological balance, cultural heritage, and traditional practices of the region. This monograph series is dedicated to exploring and documenting the indigenous plants that thrive along this sacred river, from the high-altitude regions of Uttarakhand to the fertile plains of West Bengal. These plants are not merely biological entities; they are part of the cultural and spiritual fabric of the communities that have lived along the Ganga for generations. They are used in traditional medicine, rituals, and daily life, and they play a crucial role in the local economies.

The journey from Uttarakhand to West Bengal covers a vast array of ecosystems, from the alpine forests of the Himalayas to the mangroves of the Sundarbans. At each of the 26 sites we studied, the selected plant species reflect the unique environmental conditions and cultural practices of the region. This series of monographs is a culmination of an extensive research initiative aimed at understanding and preserving the botanical wealth of the Ganga basin. A total of 26 key sites along the river, spanning the length from its source in Uttarakhand to its mouth in the Bay of Bengal, were explored, analysed, and documented. At each of these sites, the indigenous plant species were studied which are adapted to the unique environmental conditions present. The exploration focuses on ten plant species that are not only emblematic of the region but also hold significant ecological, medicinal, and cultural value.

Each monograph in this series provides a comprehensive overview of the plant species, detailing its botanical characteristics, ecological role, traditional uses, and cultural significance. The data for distribution of these plants along the Ganga, highlighting the environmental factors that influence their growth and survival is primarily focussed. To achieve a comprehensive understanding, the selected sites were explored for their botanical diversity, phytochemical properties of the plants, and soil properties examination of each area. Additionally, *insilico* analysis was conducted to assess the plants' potential in combating several diseases. The study also investigated the ethnomedicinal and pharmacological uses and applications of these plants, complemented by a bibliometric analysis to evaluate existing research and knowledge. This exploration also presents as a fresh insight to classical literature of Ayurveda in the form of "Shlokas" and therefore extending beyond the identification of individual species; it adds a fresh perspective to the existing literature and delves into uncovering the intricate web of life that sustains these plants and the human communities that rely on them.

Patanjali Group recognized the critical need to explore the diverse botanical landscape of the Ganga River basin and to conduct scientific, evidence-based research to highlight its ecological and medicinal significance. With this vision, Patanjali Organic Research Institute embarked on an initiative to systematically document and analyse the indigenous plant species found across this region. The goal is to develop scientifically validated insights into the botanical diversity, phytochemical properties, and ethnomedicinal uses of these plants, thereby creating a comprehensive understanding of the current status and challenges associated with preserving this rich natural heritage.

We express our deepest gratitude to Param Pujya Swami Ramdev Ji for his unwavering leadership and support throughout this endeavour, as well as for his invaluable guidance in every aspect of our work. My best wishes to the dedicated and highly skilled experts, who have meticulously gathered data and conducted extensive research on the diverse botanical heritage of the Ganga River basin, utilizing cutting-edge scientific techniques and methodologies. Nature holds immense potential for sustainable practices and this project is a significant contribution to the preservation of these indigenous plant species, ultimately benefiting both ecological balance and the well-being of the communities that rely on them.

आचार्य बालकृष्ण

Dr. Acharya Balkrishna



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Classical Ayurvedic Insight

Ricinus communis L.

Vedic name : (Eraṇḍakaḥpañcāṅgulaḥ) (एरण्डकः पञ्चाङ्गुलः)

Botanical name : *Ricinus communis* L.

Utpatti sthānam

Uṣṇatakaṭibandhīyetathaivamūlatakhalu.

Upoṣṇakaṭibandhīye'phrīkābhūbhāgatastathā.

Samastebhāratesārdhasahasravāmakocchrite. (SaumitreyaMahodadhiḥ: 1-2)

Distribution

It is native to tropical Africa, widely distributed in the tropics and subtropics. Throughout India it found to an altitude of 2000 m mostly under cultivation.^[1-6]

Vānaspatikavivaraṇam

1. Kāyikalakṣaṇam

Eraṇḍavaṃśasaṃbhūtapādapo'yaṃvirājate.

Caturvyāmasamucchrāyo'romaśovārṣiko'thavā.

Vartatebahuvarṣāyurnīlacchāyāsamanvita.

Mṛdukāṣṭhakṣupaścā''ho hrasvakovṛkṣaucyate.

Kāṇḍantusuśiratvenacāthavāmajjasamṃyutam.

Ādhārekilakāṣṭhatveparivartitarūpadhṛk.

Prāyobhagnasvabhāvañcaprarohobhāsvaratvata.

Tvaksadātanurūpeṇadhūsarababhruvarṇata.

Patramekāntarañcarjuhastābhasaptapālikam.

Āyāmikrakacākārapālikamharitamkvacit.

Pādonahastakavyāsātsārdhahastasuvigraham.

Jālamayaśarīrañcadīrghāyatāccarekhitam.

Tīkṣṇāgramvā'thalambāgramgranthilakrakacābhakam.

Pārśvasthatantrikājātaṃvartatedaśayugmata.

Viṃśatiyugaleṣvevamupāntānniyatatvata.

Parṇavṛntaṃbhavedatrapañcāṅgulavilambitāt.

Pañcadaśāṅgulocchrāyaṃśīrṣe ca granthilamśadā.

Tad vibhinnaprakāreṇagranthilampratibhāsate.

Anupatraṃbhavedatrasahajātaṃtathaiva ca.

Pādonavyāmakocchrāyāddvivāmalambitamśadā. (SaumitreyaMahodadhiḥ: 2-12)

Botanical Description

1. Vegetative Characters

A tall, glabrous and glaucous, evergreen annual or perennial bush or a small, soft-wooded tree up to 6 m tall whole plant often reddish or purplish. Stem hollow or pithy becoming woody at the base, often brittle, shoots glucose with their grayish brown bark. Leaves simple, alternate, broad, palmately 7-many lobed, lobes serrate, green or reddish, 30-60 cm in diameter, membranous, ob-long to linear, acute or acuminate, gland-serrated, lateral nerves 10-20 pairs, running to the margins. Petioles 10-30 cm long, with conspicuous glands at the tip. Petiolar glands are variously shaped. Stipules connate, 2-3 cm long. ^[1-6]

2. Kāyikalakṣaṇam

Puṣpīyalakṣaṇepuṣpaṃbṛhadbhātikadācana.
Sarale sthūlarūpe ca tathaivā'ntastharūpiṇi.
Sagucche cāpyasīmākṣedalenarahitaṃsadā.
Tatparidalapuñjantusaralaṃhīnabimbakam.
Nṛpuṣpaṃtuprasūnānāṃkrametūrdhvaṃpratīhavai.
Sagucchaṃtrīprasūnantutadadhobhāgaeva ca.
Sagucchaṃpratibhāsetapuṃspuṣpantuviśeṣata.
Ardhāṅgulayavavyāsaṃtatraivaṃpuṣpavṛntakam.
Sārdhadviyavakocchrāyādyavonāṅgulalambitam.
Bāhīkadalapuñjantudīrghavṛttāṇḍakākṛti.
Triyavalambitātkvāpicaturyavavilambitam.
Sārdhayavāyatānnūṃdvīyavāyāmasaṃbhṛtam.
Jālamayañcatīkṣṇāgraṃpītābhaharitantathā.
Prāntasparśitrikhaṇḍītapañcakhaṇḍyāṃvibhājitam.
Puṃskesarāstathānaikecaturyavavilambitāḥ.
Puṃstantuḥsahajātovāśākhitagucchajātake.
Prasūnadhūlikośasthakośikāsūkṣmatasthitā.
Spaṣṭāpāṇḍurapītā ca dūrasthāprāyaśapuna.
Golākārayutāceyaṃvibhātidvivibhājitā.
Bandhyāḥtrīkesarāstāvannopatiṣṭhantitatravai.
Trīpuṣpavṛntamapyatrasārdhadviyavalambitāt.
Ardhāṅgulasamucchrāyaṃphaletvaṅgulalambitam.
Tato'dhikasamucchrāyaṃkvacinnūṃnibhālyate.
Bāhīkadalapuñjañcapṛthuparṇisvarūpata.
Āśupāti ca vartetatathātatrā'ṇḍakāsaya.

Trikoṣṭhakayutobhātivartikātuyavocchritā.
 Sārdhadviyavakocchrāyākvacitsāpratibhāsate.
 Pūrṇābhṛatsvarūpā ca bahudhāsāndravarnagā.
 Dvidhāvibhājītācāpivistṛtāpakṣalāpi ca.
 Aṅkurakairyutābhātiphalantugolakākṛti.
 Ardhaṅgulayavocchrāyātsapādāṅgulalambitam.
 Dīrghāyatantathāślakṣṇamathavākaṇṭakisphuṭam.
 Sādhāraṇatayānūnaṁkomalakaṇṭakairvṛtam.
 Tridhāprasphuṭitamṭaccadvikavāṭavapurdharam.
 Sampuṭakañcabhāsetabījaṁbhāsavaravarṇakam.
 Sārdhatriyavakākārātṣaḍyavākārasaṁbhṛtam.
 Dhūsaraṁśubhavarṇaṅcaprāyodīrghāyatamṁbhavet.
 Bījānāṁkavacastāvadvartateparpaṭīmaya.
 Naikākārayutaścāpi naikavarṇasamanvita.
 Salakṣmācikkaṇobhātitaṭprasūnaphalodaya.
 Māsādbhādrapadādyaḍvadvaiśākhaṁparidṛśyate. (Saumitreyā Mahodadhiḥ: 12-32)

2. Floral Characters

Flowers monoecious, rather large, born in erect stout terminal sub-paniculate racemes, apetalous. Perianth simple and without any disk. Male flowers crowded in the upper portion of the inflorescence while female below. Male flowers 1.2 cm in diameter. Pedicels 5-17 mm long. Calyx elliptic-ovate, 6-8 × 3-4 mm long and wide, acute, yellowish-green, membranous, splitting valvately in to 3-5 segments. Stamens many, 7-8 mm long. Filaments crowded variously connate or in branching clusters. Anther-cells 0.5 mm. long, pale yellow, distinct, distant, subglobose, divergent. Pistillode absent. In female flower pedicels 5-10 mm long extending to 2 cm or more in fruit. Calyx spathaceous, caducous. Ovary trilocular. Style 2-5 mm long, entire, large, bifid or 2-partite, often highly colored, spreading, feathery or papillose. Fruits globose capsule, 1.2-2.5 cm long, oblong, smooth or echinate usually covered with soft spines, dehiscing into three, 2-valved cocci. Seeds 7-12 × 5-8 × 4-6 mm, shiny, grayish, silvery or beige, generally streaked and flecked with brown, oblong. Testa crustaceous, variable in size, smooth, variously coloured, mottled. Flowering/ fruiting September-April. ^[1-6]

Plant Anatomy

Prayojyāṅgam

Eraṇḍakasyatatpañcāṅgulakasyapracoditam.

Prayojyāṅgaṁbudhairmūlamantaḥsaṁracanocyate. (SaumitreyāMahodadhiḥ: 1)

Antaḥsaṃracane kṣaṇe

(a) Mūlabhāgaḥ

Adhitvakprotakamlambāstanubhittīyakośikāḥ.
Dvītīyakākhyasalkānitanubhittīyakānyapi.
Sparśarekhīyakālambakośikāḥśalkasaṃyutāḥ.
Saṃkucitāstathāgolapralambasparśarekhikāḥ.
Tanubhittīyakāstatramṛduta kīyakośikāḥ.
Bhavanti cāthata tailabindūnāmapyupasthitiḥ.
Cūrṇātukṣāarakasyātrakaṇādrīśyāvṛtīyakāḥ.
Saraḷā uta saṃyuktāmatāmaṇḍakaṇāapi.
Cālanīnālikāḥpoṣavāheṣuvilasantyapi.
Mṛdavaḥpoṣavāhāścatattantuvyūhasaṃyutāḥ.
Tantavolambakāstatrasthaulyayuktāpaṭānvitāḥ.
Saṃkīrṇaguḥīkāvyūhaiḥsamanvitābhavantivai.
Tantuvrajaḥpunaḥkaścitsaṃkedrakośikānvitāḥ.
Paṃktibaddhaścacūrṇātukṣāraṇaprapūritaḥ.
Cālanīnālikāḥpoṣavāhāścāpimṛduta kāḥ.
Tanubhittisaṃyuktakośikābhīryutāstathā.
Antarbhāgeṣute poṣavāhāḥsamadhikaṃspuṭāḥ.
Trito vaipañcaparyantaṃstarīyāedhikāapi.
Āyatākārarūpiṇyastāḥpunaḥsamupasthitaḥ.
Nyagvāhomūlabhāgasyrjatyādhikyamatravai.
Pañcādikohyasaudrīyobhavatisūkṣmikāyane.
Vāhikāmṛdulāstantusandohenasamanvitāḥ.
Tan nyagvāhaprabhāgeṣuvāhikāḥsamarūpataḥ.
Ekalāḥsamavāyeṣupravikīrṇābhavantivai.
Nyagvāhatantavolambāstasminmaṇḍakaṇāapi.
Sthūlabhittimayādrīśyābhavantisūkṣmadarśane.
Ekatodvikaparyantaṃpaṃktibaddhāyathāyatham.
Madhyāṃśaraśmayodrīśyābhavanti prasamīkṣaṇe. (SaumitreyaMahodadhiḥ: 2-15)

Plant Parts

Roots

Microscopic Characters

Root

Beneath cork is elongated, thin walled cells are found. Secondary cortex is thin-walled, tangentially elongated cells and narrow cortex of rounded to tangentially elongated thin-walled parenchymatous cells. It contains large oil globules, calcium oxalate crystals and round simple or compound starch grains. Phloem consists sieve tubes, phloem parenchyma and phloem fibres. Fibres are long, septate, highly thickened and with narrow lumen. Some fibres are surrounded by concentric rows of cells containing crystals of calcium oxalate, sieve tubes, thin walled with companion cells and phloem parenchyma. Phloem is more prominent in inner region. Cambium is 3-5 layered, rectangular in shape. Xylem occupies major part of root and pentarch. Xylem consists vessels, parenchyma and fibres. Vessels are uniformly scattered throughout the xylem region, either solitary or in groups. It contains starch grains, xylem fibres long and thick-walled. Medullary rays are uni- to biseriate. ^{[1], [7-8]}

Medicinal Uses

Ophthalmic diseases

Eraṇḍapallavemūletvacivā"jampayahśṛtam.....Sukhoṣṇamsecanehitam.
(Su.U. 9: 11-12)

Eraṇḍadalamūlatvakchṛtamājampayohitam.

Sukhoṣṇamnetrayosiktamvātābhiṣyandanāśanam. (Bhā.Pra.Ci. 63: 142)

Taruṇamurubūkapatrammūlañcavibhidhasiddhamājekṣīre.

Vātābhiṣyandarujamṣadyovinihantisaktupiṇḍikācoṣṇā. (A.Hṛ.U. 16:10)

Vāta associated conjunctivitis- Tender leaves and rootbark of *Ricinus communis* (Castor-oil plant) processed with goat milk used as an eye drop or parched flour mixed in this milk applied lukewarm locally over the eyes is useful in alleviating the pain caused due to *Vāta* associated conjunctivitis and glaucoma. ^{[9](Su.Ut.9:11-12), [10] (Bh.Pr.63:142), [11] (As.Hr.Ut.16:10)}

Eraṇḍapatramūlatvaknirmitāvātānāśinī. (Śā.Saṃ.U.Kha. 13: 26)

Vāta associated eye diseases- Potli prepared from *Ricinus communis* (Castor-oil plant) leaves, root and bark paste tied in a cloth; over the eyes is useful in alleviating *Vāta* associated eye diseases. ^{[12] (Shr.Sm. Ut.Kh. 13:26)}

Eraṇḍapatrasaptakaraso'thavāsaindhavasamṣuktaḥ.

Navadṛkkopaśamanah..... (Vaṃ.Se.Netraroge 34-35)

Juice extracted from *Ricinus communis* (Castor-oil plant) leaves mixed with rock salt used as an eye drop is useful in treating acute eye diseases. ^{[13] (Vg.Sn.Netra:34-35)}

Eraṇḍamūlaṃsaphalaprarohaṃvirjaraṃkṣīrayutaṃgavāṃ ca.

Syādvātaraktāpahamugrametadāścotanaṃsadbhiṣajavadanti. (Ga.Ni.Śā.Taṃ. 3: 126)

Vāta and vitiated blood associated eye diseases- *Ricinus communis* (Castor-oil plant) root, fruit and shoot pounded with cow milk, filtered well, used as an eye drop is beneficial in treating *Vāta* and blood associated eye diseases. [14] (Gd.Ni.Sha.T 3:126)

Payovimiśraṃpavanodbhavehitamvadantipañcāṅgulatailamevatu.(Su.U. 17:29)

Blindness- In case of *Vāta* associated cataract, 4-16ml *Ricinus communis* (Castor-oil plant) oil should be used along with 200ml milk for purgation. [9] (Su.Ut. 17:29)

Snehanecāgryamairāṇḍamtuviṛecane. (Ca.Sū. 13: 12)

Night Blindness- Leaves of *Ougeiniaoojeinensis* (Sandan), *Ricinus communis* (Castor-oil plant), *Vitex negundo* (Five leaved-chaste tree) and *Asparagus racemosus* (Asparagus), cooked in *Ghṛta* (Clarified butter) is wholesome in treating night blindness. [15] (Ca.Su.13:12)

Ear diseases

Eraṇḍapatrapuṭapākavipācitāmbutulyārdrakasyasalilaṃmadhukēnamīśraṃ.

Paktvā ca tailalavaṇenayutaṃsukhoṣṇaṃkarṇerujaṃharatitakṣaṇamevadattam.

(Vaṃ.Se.Karṇarogaḥ 38)

Otalgia- Juice extracted from *Ricinus communis* (Castor-oil plant) leaves through *Puṭapāka* method, *Zingiber officinale* (Wet ginger root) juice and *Glycyrrhiza glabra* (Liquorice root) paste processed with oil mixed with rock salt and administered as ear drops quickly relieves otalgia. [13] (Vg.Sn.Karna:38)

Eraṇḍaśigruvaruṇamūlikāpatraje rase.

Caturguṇepacettailaṃkṣīrecāṣṭaguṇānvite.

Yaṣṭyāhvakṣīrakākōlikakayuktaṃnihanti tat.

Nāḍabāḍhiryāśūlānināvanābhyamgaṇapūraṇaiḥ. (Vaṃ.Se.Karṇarogaḥ 57-58)

Take 4 parts each of *Ricinus communis* (Castor-oil plant), *Moringa oleifera* (Drumstick tree), *Raphanus sativus* (Radish), *Crataevanurvala* (Three leaved caper) leaf juice, 8 parts milk and 1/4-part *Glycyrrhiza glabra* (Liquorice root) and *Lilium polyphyllum* (White himalayan lily) paste used as for errhine, massage and for ear filling is useful in treating tinnitus, deafness and otalgia. [13] (Vg.Sn.Karna.57-58)

Thoracic diseases

Eraṇḍapatrakṣāraṃvāvyoṣateluguḍānvitam.

Liḥyādetenavidhināsurasairāṇḍapatrajam. (Ca.Ci. 18: 171)

Cough- Licking up of *Ricinus communis* (Castor-oil plant) leaf *Kṣāra* or *Ocimum sanctum* (Holy Basil) leaf and *Ricinus communis* (Castor-oil plant) leaf *Kṣāra* mixed with equal quantity of *Trikaṭu*, oil and jaggery is useful in treating cough. [15] (Ca.Ci. 18:171)

.....eraṇḍamūlaṃdvipalaṃjale'ṣṭaguṇepacet.

Tatkvāthoyāvaśūkāḍhyaḥpārśvahrṭkaphaśūlahā. (Śā.Saṃ.Ma.Kha. 2: 101)

Flank pain- Drinking of 50ml of the decoction prepared from 50gm *Ricinus communis* (Castor-oil plant) root cooked in 8 parts of water till it remains one-fourth and mixed with 1gm *Yavakṣāra* is useful in

alleviating flank pain, angina and *Kapha* associated pain. ^[12] (Shr.Sm.Md.Kh. 2:101)

Eraṇḍatailamathavāmadyamastupayorasai. (Su.U. 42: 122)

Intake of *Ricinus communis* (Castor-oil plant) oil along with alcohol, whey or milk according to the patient's strength, *doṣa*, *Sātmya* etc. is beneficial. ^[9] (Su.Ut. 42:122)

Abdominal diseases

Payasāmāmsarasairvātriphalārasayūṣamūtramadirābhiḥ.

Doṣānubandhayogātpraśastamairaṇḍajamtailam. (Ca.Ci. 26: 29)

Flatulence- Intake of *Ricinus communis* (Castor-oil plant) oil in an appropriate dose along with milk, meat soup, *Triphalā*(combination of three fruits) [*Embllica officinalis* (Indian goose berry), *Terminalia chebula*(Black myrobalan), *Terminalia bellirica* (Bedda nut)] decoction, cow urine or medicated alcohol as Anupāna according to *doṣa* is useful in the treatment of *Gulma*, abdominal diseases, hemorrhoids, flatulence, vaginal diseases, *Vāta* associated diseases, etc. ^[15] (Ca.Ci.26:29)

Tathā'timuktakairāṇḍaśephālyamīrujāni ca.

Bhr̥ṣṭamghṛtamkumbhayoneḥpatraiḥpāne ca pūjitam. (A.Hr.U. 13: 90)

Constipation- In case of constipation, *Ricinus communis* (Castor-oil plant) oil is the drug of choice for inducing purgation. ^[11] (As.Hr.Ut.13:90)

Vibaddhavātavarcāstubahuśūlapravāhikaḥ.

Saraktapicchastṛṣṇārtahkṣīrasauhityamarhati.

Yamakasyoparikṣīramdhāroṣṇamvāprayajayet.

Śṛtameraṇḍamūlenabālabilvenavāpunah. (A.Hr.Ci. 9: 37-38)

Śṛtamairaṇḍamūlena. payah.

Evaṁkṣīraprayogeṇaraktampicchā ca śāmyati.

Śūlampravāhikācaivavibandhaścopaśāmyati. (Ca.Ci. 19: 48-49)

Diarrhea- Intake of milk processed with *Ricinus communis* (Castor-oil plant) root decoction or paste is useful in treating constipation, colic, dysentery and bloody diarrhea caused due to abnormal movements of Vāyu is very much beneficial. ^[11] (As.Hr.Ci.9:37), ^[15] (Ca.Ci.19:48-49)

Athavairaṇḍasiddhenapayasākevalenavā.

Yavāgūrvitareccāsyavātaghnairdīpanaiḥkṛtāḥ. (Su.U. 40: 130)

Milk processed with *Ricinus communis* (Castor-oil plant) used as a laxative followed with Yavāgū processed with Vātahara and Dīpana herbs should be given to the patient suffering from diarrhea. (If a patient is having good digestive strength). ^[9] (Su.Ut.40:130)

Samñjātabalakāyāgniṁpunahsnigdhamvirecayet.

Payasāsatrivṛtkalkenorubūkaśṛtenavā. (Ca.Ci. 13: 69)

Abdominal diseases- In *Pitta* associated abdominal disorders, after detoxification therapy and regaining the strength, milk processed with *Ricinus communis* (Castor-oil plant) root decoction should be given as a laxative after repeated oleation therapy. ^[15] (Ca.Ci.13:69)

Eraṇḍatailamaharaharmāsamdvauvākevalamūtrayuktaṁkṣīrayuktaṁvāsevetodakavarjī.
(Su.Ci. 14:10)

Pāyayettailamairāṇḍaṁsamūtraṁsapayo'pivā. (A.Hr.Ci. 15:2)

Intake of *Ricinus communis* (Castor-oil plant) oil along with cow urine or cow milk regularly for 2 months for laxation helps in elimination of the collected faecal matter which results in purification of channels. Use of water is contraindicated during this period. ^[9] (Su.Ci.14:10), ^[11] (As.Hr.Ci. 15:2)

Kaphevātenapittevātābhyāmvā'pyāvṛte 'nile.

Balinaḥsvauśadhayutaṁtailameraṇḍajaṁhitam. (A.Hr.Ci. 15:47)

In case of abdominal diseases when *doṣa* get reciprocally obstructed, use of *Ricinus communis* (Castor-oil plant) oil is very much beneficial. ^[11] (As.Hr.Ci.15:47)

Eraṇḍatailamdaśamūlamiśraṁgomūtrayuktastriphalārasovā.

Nihantivātodaraśoṭhaśūlaṁkvāthaḥsamūtrodaśamūlajaśca.(Vṛ.Mā.38:2)

Abdominal swelling- Intake of *Daśamūla* (group of roots of ten medicinal herbs) decoction mixed with *Ricinus communis* (Castor-oil plant) oil is useful in alleviating *Vāta* associated abdominal swelling and colic. ^[16] (Vṛ.Mā.38:2)

Pibedairāṇḍajaṁtailamvāruṇīmaṇḍamiśritam.

Tadevatailampayasāvātagulmīpibennaraḥ.

Śleṣmaṇyanubalepūrvamhitamṁpittānugeparam. (Ca.Ci. 5: 92-93)

Gulma- In *KaphānuvandhīVātaGulma* (Kapha associated VātaGulma) and *PittānuvandhīVātaGulma* (Pitta associated VātaGulma), intake of *VāruṇīMaṇḍa* (Medicinal preparation) along with castor oil and milk along with castor oil is used respectively. ^[15] (Ca.Ci. 5:92-93)

Tailameraṇḍajaṁvā'pimadhukakvāthasaṁyutam.

Śūlaṁpittodbhavaṁhanyādgulmaṁpaittikameva ca. (Ca.Da.Ci. 26: 32)

Intake of *Glycyrrhiza glabra* (Liquorice root) decoction mixed with *Ricinus communis* (Castor-oil plant) oil is useful in alleviating *Pitta* associated *Gulma* and *Pitta* associated pain. ^[17] (Ca.Dt.Ci.26:32)

Viśvameraṇḍajaṁmūlaṁkvāthayitvājalaṁpibet.

Hiṅgusauvarcalopetaṁsadyaḥśūlanivāraṇam. (Bhā.Pra.Ci.30: 41)

Intake of the decoction prepared from *Ricinus communis* (Castor-oil plant) root and *Zingiber officinale* (Dry ginger root) in a dose of 50-100ml mixed with 1gm each of *Ferula nartex* (Asafoetida) and *Sauvarcala* salt is useful in alleviating abdominal pain. ^[10] (Bh.Pr.Ci 30:41)

Eraṇḍaphalamūlānimūlaṁgokṣurasya ca.

Śālaparṇīmpṛśniparṇīmbṛhatīmkaṇṭakārikām.....

Vātikaṁpaittikaṁvā'piślaiśmikaṁsannipātikam.

Prasahyanāśayecchūlaṃchinnābhramivamārutaḥ. (Su.U. 42: 112-115)

Intake of the decoction prepared from *Ricinus communis* (Castor-oil plant) fruit and root, herbs of *Teramnus labialis* (Blue wiss), *Vigna trilobata* (Jungle mat bean), *Hygrophila auriculata* (Marsh barbel), *LaghuPañcamūla*, *Desmodiumgangeticum* (Sal leaved desmodium), *Vernonia cinerea* (Little ironweed) root mixed with *Yavakṣāra* is useful in quick alleviation of the pain caused due to *doṣa*'s. [9] (Su.Ut. 42:112-115)

Eraṇḍamethikāguḍaniryūhoharatijaṭharaśūlāni. (Si.Bhe. Ma. Caturthagucchaśūla ci. : 2)

Colic- *Ricinus communis* (Castor-oil plant) root, *Trigonella foenum-graecum* (Fenugreek) and jaggery decoction is useful in quick relief of abdominal colic. [18] (Sd.Bh.Mm.Ch.Shool.Ci:2)

Nāgarairāṇḍajaḥkvāthaḥkvāthaimḍrayavasya ca.

Hiṃgusauvarcalopetovātaśūlanivāraṇaḥ. (Śā.Saṃ.Ma.Kha. 2: 98)

Vāta associated pain- Intake of 50ml *NāgarādiKwātha* (Medicinal preparation) and *Ricinus communis* (Castor-oil plant) root decoction mixed with 1gm each of roasted *Ferula nartex* (Asafoetida) and *Sauvarcala* salt is useful in alleviating *Vāta* associated pain. [12] (Shr.Sm.Md.Kh. 2:98)

Ano-rectal diseases

Vṛśārkairāṇḍabilvānāmpatrotkvāthaiścasecayet. (Ca.Ci. 14: 44)

Hemorrhoids- Decoction of the leaves of *Ricinus communis* (Castor-oil plant), *Adhatodavasica* (Malabar nut), *Calotropis procera* (Rubber bush) and *Aegle marmelos* (Indian quince) should be used for sudation in hemorrhoids. [15] (Ca.Ci.14:44)

Eraṇḍatailaṃtriphalārasena ca viśodhanam.

Viṭpittaśleṣmavātānulanādgudajāpaham. (Ga.Ni.Kā.Ci. 4: 103-104)

Eraṇḍatailaṃtriphalākvāthenadviguṇena ca.

Yuktampītaṃpayobhīrvānacireṇaviricyate. (Śā.Saṃ.U.Kha. 4: 20-21)

Ricinus communis (Castor-oil plant) oil mixed with *Triphalā*(combination of three fruits) juice or double quantity of *Triphalā*(combination of three fruits) powder or double quantity of milk taken internally induces detoxification of the body and hence useful in treating hemorrhoids. [14] (Gd.Ni.Ky.Ci.4:103-104), [12] (Shr.Sm. Ut.Kh.4:20-21)

Hepatosplenic diseases

Kālārtastutaruṇaṃbhuñjītatridinaṃprage.

Kāmalāyāḥpraśāntyarthaṃvaikuṇṭhaṃpāyayennaraḥ. (Vai.Ma. 10:5)

Jaundice- Intake of *Ricinus communis* (Castor-oil plant) and *Ocimum sanctum* (Holy Basil) mixed water for three days is useful in treating jaundice. [19] (V.Mn.10:5)

Reproductive diseases

Svinnaṃcainaṃyathānyāyāṃpāyayetvirecanam.

Kośāmratilvakairāṇḍaphalatailānivānaram.

Sakṣīraṃvāpibenmāsaṃtailameraṇḍasambhavam. (Su.Ci. 19: 6)

Hernia- In *VātajaVṛddhīroga* purgation given with *Schleichera oleosa* (kusum tree), *Tilwaka* milk along with *Ricinus communis* (Castor-oil plant) oil is beneficial. ^[9] (Su.Ci. 19:6)

Guggulurūbutailaṃ vāgomūtreṇapibennaraḥ.

Vātavṛddhiṃnihantyāśucirakālānubandhinīm.

Sakṣīraṃvāpibettailaṃmāsameraṇḍasambhavam. (Vṛ.Mā. 40:2)

Intake of *Commiphora wightii* (Gum guggul) along with *Ricinus communis* (Castor-oil plant) oil or milk along with *Ricinus communis* (Castor-oil plant) oil for one month is useful in alleviating *VātajaVṛddhī*. ^[16] (Vṛ.Ma. 40:2)

Rāsnāyaṣṭyamṛtairāṇḍabalāgokṣurasādhitaḥ.

Kvātho'ntravṛddhiṃhantyāśurubutailenamiśritaḥ.

Tailameraṇḍajaṃpītvābalāsiddhaṃpayonvitam.

Ādhmānaśūlopacitāmantravṛddhiṃjayennaraḥ. (Vṛ.Mā. 40:11-12)

Intake of the decoction prepared from *Pluchea lanceolata* (Rasna), *Glycyrrhiza glabra* (Liquorice root), *Tinospora cordifolia* (Tinospora), *Ricinus communis* (Castor-oil plant), *Sida cordifolia* (Country mallow) and *Tribulus terrestris* (Puncture vine) (50ml) mixed with one-fourth part of castor oil or drinking of milk processed with *Sida cordifolia* (Country mallow) and castor oil is beneficial in alleviating distension and painful hernia. ^[16] (Vṛ.Ma. 40:11-12)

Yoniśūlaharamnārīyonyāṃprakṣipyadhārayet.

Picumerāṇḍabījaṃtupariḡhyavidhānataḥ. (Ga.Ni.Kau.Ta. 6: 8)

Vaginal pain- Withholding of tampon prepared from the cotton wrapped with peeled off seed of *Ricinus communis* (Castor-oil plant) is useful in alleviating vaginal pain. ^[14] (Gd.Ni.Kau.Tn. 6:8)

Eraṇḍatailenapariplutāsyātkārpāsapiṇḍīyadionimadhye.

Śūlaṃtadānīmśamayettadiyaṃsaṃyāvakoṃuṇḍatikākṛtovā. (Ga.Ni.Kau.Taṃ. 6: 16)

Cotton piece kept within the vagina soaked properly in *Ricinus communis* (Castor-oil plant) oil or application of the paste prepared from *Sphaeranthus indicus* (East Indian Globe Thistle) paste cooked in castor oil within the vagina is useful in alleviating vaginal pain. ^[14] (Gd.Ni.Kau.Tn. 6:16),

Eraṇḍasya ca bījānimātuluṅgasyacaiva hi.

Sarpiṣāparipiṣṭānipibedgarbhapradāni ca. (Ga.Ni.Kau.Taṃ. 5: 4)

For conception- Equal quantity of *Ricinus communis* (Castor-oil plant) seed and *Citrus medica* (Citron) seeds pounded with *Ghṛta* (Clarified butter) and taken internally induces quick conception. ^[14] (Gd.Ni.Kau.Tn. 5:4),

Musculoskeletal diseases

Āmavātagajendrasyaśarīravanacārīṇaḥ.

Eka evanihatyāśueraṇḍatailakeśarī. (Bhā.Pra.Ci. 26: 50)

Rheumatoid arthritis- *Ricinus communis* (Castor-oil plant) oil is useful in the treatment of rheumatoid arthritis. ^[10] (Bh.Pr.Ci.26:50)

Śuṇṭhīkalkaṃvinikṣipyarasaṃraṇḍamūlajaiḥ.

Vipacetpuṭapākenatadrasaḥkṣaudrasaṃyutaḥ.

Āmavātasamudbhūtāmpīḍāṃjayatidustarām. (Śā.Saṃ.Ma.Kha. 1: 41-42)

2 parts *Ricinus communis* (Castor-oil plant) root juice and 1 part *Zingiber officinale* (Dry ginger root) paste cooked through Puṭapāka method and juice is extracted from it, intake of 20-25ml of this juice mixed with honey is useful in alleviating rheumatic pain. ^[12] (Shr.Sm.Md.Kh.1:41-42)

Gandharvahastamuṣkakanaktamālātarūṣakapūṭikāragvadhacitrakādīnām
patrāṇyādrāṇilavaṇena.

Sahodūkhale'vakṣudyasnehaghaṭeprakṣipyāvalipyagośakṛdbhirdāhayet.

Etat patralavaṇamupadiśantivātarogeṣu. (Su.Ci. 4:30)

Vāta associated disorders- Fresh leaves of *Ricinus communis* (Castor-oil plant), *Schreberaswietenoides* (Weaver's beam tree), *Pongamia pinnata* (Pongam oil tree), *Adhatodavasica* (Malabar nut), *Holoptelea integrifolia* (Indian elm), *Cassia fistula* (Indian laburnum) and *Plumbago zeylanica* (Ceylon leadwort) mixed with equal quantity of rock salt, stored in an earthen pot smeared with *Ghṛta* (Clarified butter), cooked through Puṭapāka method. The salt obtained from this is wholesome in treating Vāta associated disorders. ^[9] (Su.Ci.4:30)

Eraṇḍatailayuktāṃharītakīmḥbhakṣayennarovidhivat.

Āmānilārttiyuktogṛdhrasīvrddhyarditoniyaṭam. (Vṛ.Mā. 25:21)

Rheumatoid arthritis- Regular intake of *Ricinus communis* (Castor-oil plant) oil mixed with *Terminalia chebula* (Myrobalan) powder in an appropriate dose is useful in treating rheumatoid arthritis, sciatica, hernia and bell's palsy. ^[16] (Vr.Ma.25:21)

Secanañcāmavātasayarubūkapayasā'pivā. (Bhā.Pra.Ci. 26:51)

Sprinkling done with *Ricinus communis* (Castor-oil plant) decoction is useful in alleviating rheumatoid arthritis. ^[10] (Bh.Pr.Ci.26:51)

Kṣīrapīṣṭam.....eraṇḍasyaphalāni ca.

Kuryācchūlanivṛttyartham.....(Ca.Ci. 29: 140)

Gout- *Ricinus communis* (Castor-oil plant) fruit pounded with milk, applied externally is useful in alleviating pain. ^[15] (Ca.Ci.29:140)

Kṣīreṇairaṇḍatailamvāprayogeṇapibennaraḥ.

Bahudoṣovirekārthamjīrṇekṣīraudanāśanaḥ. (Ca.Ci. 29: 83)

Intake of 10-25ml *Ricinus communis* (Castor-oil plant) oil along with milk followed with the diet of cooked rice after its proper digestion is beneficial in treating Vāta associated gout. ^[15] (Ca.Ci. 29:83)

Kṣīreṇairaṇḍatailañcaprayogeṇapibennaraḥ.

Bahudoṣovirekārthamjīrṇekṣīraudanāśanaḥ. (A.Hṛ.Ci. 22.11)

If Tridoṣa are vitiated together in gout, then purgation should be done with milk containing *Ricinus communis* (Castor-oil plant) oil. Milk and rice should be used as a wholesome diet. ^[11] (As.Hr.Ci.22:11)

Palatrayamkaṣāyasyatriphalāyāhsucūrṇitam.

Saugamdhikapalañcaivamkauśikasyapalatrayam.

Kuḍavaṃcitratailasyasarvamādāyayatnataḥ.

Pācayetpākavidvaidyaḥpātrelohamayedṛdhe.

Hanti vātaṃtathāpittaṃślaiṣmiṇaṃkhañjapamgutām.

Śvāsaṃsudurjayamhantikāsaṃpamcavidhamtathā. (Vaṃ.Se.Vātaraktaḥ 173-179)

Intake of Siṃghanāda Guggulu [prepared from (150ml *Triphalā*(combination of three fruits) decoction, *TrijātaCūrṇa* 50gm, *Commiphora wightii* (Gum guggul) 150gm and *Ricinus communis* (Castor-oil plant) oil 200ml cooked in an iron pan)] in a dose of 250-500gm regularly is useful in alleviating *Vāta* associated disorders, dyspnea, cough, leprosy, *Gulma*, abdominal diseases and rheumatoid arthritis. ^[13] (Vg.Sn.Vat. Rk.173:179)

Siṃhāsyapañcamūlachinnaruhaṇḍagokṣurakvāthaḥ.

Eraṇḍatailarāmasaiṃdhavacūrṇānvitahpītaḥ.

Śamayativātaraktaṃtathāmvātaṃkaṭīśūlaṃ.

Mūtrapurīṣavibandhabradhnavikāraṃsudurvāram. (Vaṃ.Se.Vātaraktaḥ 50-51)

Decoction of *Adhatodavasica* (Malabar nut) root, *Tinospora cordifolia* (Tinospora), *Ricinus communis* (Castor-oil plant) root Pañcamūla and *Tribulus terrestris* (Caltrop) root mixed with castor oil, *Ferula narthex* (Asafoetida) and rock salt, taken internally is useful in treating rheumatoid arthritis, lumbago, obstructed urine and faeces and an any other such complicated diseases. ^[3] (Vg.Sn.Vat.Rk.50-51)

Vātāśramugraṃrūbutailamiśrāśuṇṭhyāmvātaṃśamayeduḍūcī.

(Vaṃ.Se.Vātaraktaḥ 49)

Regular intake of *Ricinus communis* (Castor-oil plant) oil along with *Tinospora cordifolia* (Tinospora) is useful in alleviating gout. ^[13] (Vg.Sn.Vat.Rk:49)

.....lepamerāṇḍasyaphalānivā. Kuryācchūlanivṛttyarthamśtāhvāvā'nile'dhike.

(A.Hr.Ci. 22: 34)

External application of *Ricinus communis* (Castor-oil plant) seed pounded with milk is beneficial in treating painful gout. ^[11] (As.Hr.Ci.22:34)

Tailamairāṇḍajamprātargomūtreṇapibennaraḥ.

Māsamekaṃprayogo'yamgrdhrasyūrugrahāpahaḥ. (Bhā.Pra.Ci. 24: 135)

Vāta associated disorders- Regular intake of *Ricinus communis* (Castor-oil plant) oil and cow urine for one month is useful in treating sciatica and cardiac arrest. ^[10] (Bh.Pr.Ci.24:135)

Daśamūlībalārāśnāguḍūcīśvabheṣajam.

Pibederāṇḍatailenagrdrhasīkhañjapamguṣu. (Vaṃ.Se.Vātavyādhiḥ 577)

Sciatica- Intake of the decoction prepared from *Daśamūla* (group of roots of ten medicinal herbs), *Pluchea lanceolata* (Rasna), *Sida cordifolia* (Country mallow), *Tinospora cordifolia* (Tinospora) and *Zingiber officinale* (Dry ginger root) mixed with *Ricinus communis* (Castor-oil plant) oil is useful in treating sciatica, lameness and other diseases.^[13] (Vg.Sn.Vat.Vy:577)

Pañcamūlīkaṣāyanturūbutailatrivṛdyutam.

Gṛdhrasīgulmaśūlaṃ ca pītaṃsadyoniyacchati.

(Vaṃ.Se.Vātavyādhiḥ 583) (Vṛ.Mā.22: 71)

Intake of PañcamūlaKwātha mixed with *Ricinus communis* (Castor-oil plant) oil and *Operculinaturpethum* (Indian jalap) powder is useful in alleviating the pain caused due to sciatica and *Gulma*.^[13] (Vg.Sn.Vat.Vy:583), ^[16] (Vṛ.Mā.22:71)

Gomūtrairaṇḍatailābhyāmkṛṣṇāpītāsucūrṇitā.

Dīrghakālotthitāṃhantigrdhrasīmṅkaphavātajām. (Vaṃ.Se.Vātavyādhiḥ 586)

Regular intake of equal quantity of cow urine and *Ricinus communis* (Castor-oil plant) oil mixed with *Piper longum* (Long pepper) powder is useful in treating chronic sciatica.^[13] (Vg.Sn.Vat.Vy:586)

Śuṇṭhīgandharvabījābhyāmpīṣṭābhyāmpāyasaṃpacet.

Bhakṣitaṃtatkaṭīśūlaṃgṛdhrasīmṅhantyaśaṃśayaḥ. (Vaṃ.Se.Vātavyādhiḥ 592)

Intake of Pāyasa prepared from equal quantity of *Zingiber officinale* (Dry ginger root) and *Ricinus communis* (Castor-oil plant) seed paste cooked in milk is useful in treating sciatica.^[13] (Vg.Sn.Vat.Vy:592)

Eraṇḍamūlaṃbilvaṃ ca bṛhatīkaṇṭakārikā.

Kaṣāyorucakopetaḥpītovaṅkṣaṇavastijam.

Gṛdhrasījaṃharecchūlaṃcīrakālānubandhi ca. (Bhā.Pra.Ci.24: 138)

Intake of the decoction prepared from equal quantity of *Ricinus communis* (Castor-oil plant) root, fruit pulp of *Aegle marmelos* (Bengal quince), *Solanum indicum* (Indian night shade) and *Solanum xanthocarpum* (Yellow berred night shade) (50ml) mixed with 1-2gm black salt is useful in treating groin pain, cystalgia and chronic sciatica.^[10] (Bh.Pr.Ci.24:138)

Niṣkuṣyairāṇḍabījānīpiṣṭvākṣīrevipācayet.

Tatpānantukaṭīśūlegrdhrasyāṃparamauśadham. (Bhā.Pra.Ci. 24: 137)

Intake of the paste prepared from pounded and peeled off *Ricinus communis* (Castor-oil plant) seed cooked in cow milk is useful in treating lumbago and sciatica.^[10] (Bh.Pr.Ci.24:137)

Daśamūlīkaṣāyeṇapibedvānāgarāmbhasā.

Kaṭīśūleṣupātavyaṃtailameraṇḍasambhavam. (Bhā.Pra.Ci. 26: 55) (Ga.Ni.Kā.Ci. 19: 156)

Intake of *Daśamūla* (group of roots of ten medicinal herbs) decoction or *Zingiber officinale* (Dry ginger root) decoction mixed with one-fourth part of *Ricinus communis* (Castor-oil plant) oil is wholesome in treating lumbago.^[10] (Bh.Pr.Ci.26:55), ^[14] (Ga.Ni.Kā.Ci. 19: 156)

Tailameraṇḍajamvā'pigomūtreṇapibennaraḥ.

Māsamekaṃprayogo'yamgr̥dhrasyūrugrahāpahaḥ.

(Vr.Mā. 22:81) (Vaṃ.Se.Vātavyādhiḥ 580)

Intake of *Ricinus communis* (Castor-oil plant) oil along with cow urine regularly for one month is useful in treating sciatica and stiffness of thighs. ^[16] (Vr.Mā.22:81), ^[13] (Vg.Sn.Vat.Vy:580)

Aśnātiyonaraḥsiddhāmeraṇḍaphalamiśritām.

Yavāgūmgr̥dhrasīsvinnah̥pūrvāmāpnotyasaugatim. (Vaṃ.Se.Vātavyādhiḥ 588)

Vāta associated disorders- Intake of *Ricinus communis* (Castor-oil plant) fruits or gruel processed with its fruits is useful in treating sciatica and enables normal movements in body. ^[13] (Vg.Sn.Vat.Vy:588)

Viśodhyairāṇḍabījānīpiṣṭvākṣīrevipācayet.

Tat pāyasamkaṭīśūlegr̥dhrasyāmparamauśadham.

(Vr.Mā.22:86) (Bhā.Pra.Ci. 26: 57)(Vaṃ.Se.Vātavyādhiḥ 582)

Intake of purified pounded seeds of *Ricinus communis* (Castor-oil plant) cooked in milk and made into pudding like preparation is useful in treating sciatica and lumbago. ^[16] (Vr.Ma. 22:86), ^[10] (Bh.Pr.Ci.26:57), ^[13] (Vg.Sn.Vat.Vy:582)

Eraṇḍatailaṃnirguṇḍīsvarasaṃ ca pṛthaksamam.

Pītvākaṭīpradeśasthamvātaṃjitvāsukhībhavet. (Vai.Ma. 12:8)

Intake of equal quantity of *Ricinus communis* (Castor-oil plant) oil and *Vitex negundo* (Five leaved-chaste tree) juice is useful in alleviating *Vātadoṣa* accumulated in lumbar region. ^[19] (Va.Mn.12:8)

Eraṇḍatailaṃvarcaḥsthebastisnehāścabhedinaḥ. (A.Hr.Ci. 22:62)

Intake of *Ricinus communis* (Castor-oil plant) oil, purgation, enema and cathartic diet is prescribed in *Vāta* associated with faecal matter. ^[11] (As.Hr.Ci.22:62)

Eraṇḍobījapūraścagokṣurobr̥hatīdvayaṃ.

Aśmamedastathābilvaetanmūlaiḥkṛtaḥśṛtaḥ.

Eraṇḍatailaḥimgvāḍhyaḥsayavakṣārasaindhavaḥ.

Stanaskandhakaṭīmedhrahṛdayotthāṃvyathāṃjayet. (Śā.Saṃ.Ma.Kha.2: 96-97)

Whole body pain- Intake of decoction prepared from equal quantity of *Ricinus communis* (Castor-oil plant) root, *Tribulus terrestris* (Puncture vine) root, *Citrus medica* (Citron) root, *Solanum indicum* (Indian night shade) root and *Solanum xanthocarpum* (Yellow berred night shade) root, *Bergenia ciliata* (Indian rock foil yam) root and *Aegle marmelos* (Indian quince) root, *Ferula narthex* (Asafoetida), rock salt and *Yavakṣāra* is useful in alleviating the pain manifested in breast, lumbar and cardiac region. ^[12] (Shr.Sm.Md.Kh. 2:96-97)

Diseases of extremities

.....pāyayecca tam.

Māsameraṇḍajamtailaṃgomūtreṇasamanvitam. (A.Hr.U.30: 9)

Vāta associated elephantiasis- After oleation, sudation and venesection procedures (Snehana, Swedana and Śīrāveda, 100ml cow urine mixed with one-fourth part of *Ricinus communis* (Castor-oil plant) oil

taken for one month followed with the wholesome diet is useful in treating *Vāta* associated elephantiasis.

[11] (As.Hr.Ut.30:9)

Māsamerāṇḍajamtailam̐ibenmūtreṇasaṃyutam. (Su.Ci.19:53)

Cow urine mixed with *Ricinus communis* (Castor-oil plant) oil given to the patient suffering from elephantiasis after the bloodletting for upto one month is beneficial. [9] (Su.Ci.19:53)

.....bhīkṣṇamvātakaṇṭake.

Pibederāṇḍatailamvā.....(Ga.Ni.Kā.Ci. 19: 155)

Raktāvasēcanaṃkuryādabhīkṣṇamvātakaṇṭake.

Pibederāṇḍatailamvādahetsūcībhireva ca. (Vr.Mā. 22:84)

Vāta associated disorders- Bloodletting done frequently along with drinking of *Ricinus communis* (Castor-oil plant) oil is very much beneficial in treating *Vāta* associated disorders. [14] (Gd.Ni.Ky.Ci.19:55), [16] (Vr. Mā.22:84)

Dermatological diseases

Vātāripatravṛntaprāntenādāyacūrṇakam̐bahuśaḥ.

Nighṛṣṭastēnamasaḥkaḥprasrutarudhiraḥkṣayaṃyāti. (Ga.Ni.Śa.Tam. 10: 87)

Moles- Stem of *Ricinus communis* (Castor-oil plant) is used to rub the lime over the moles repeatedly. It induces bleeding and is useful in removing the unwanted moles. [14] (Gd.Ni.Sha.T. 10:87)

Eraṇḍabhūrjapūtīkaharidrāṇām̐tuvātaje.

Dattausadheṣudātavyam̐patram̐vaidyenajānatā. (Su.Ci. 1:112-117)

Wound- *Ricinus communis* (Castor-oil plant) leaves are used for covering the wounds in *Vāta* associated wound. [9] (Su.Ci.1.112:117)

Psychological diseases

Urubūka.....tailamapatānakināṃparīṣekādiṣūpayojyam. (Su.Ci. 5: 17)

Emprosthotonus- Sprinkling of *Ricinus communis* (Castor-oil plant) oil is useful in the treatment of emprosthotonus. [9] (Su.Ci. 5:17)

Generalised body diseases

Eraṇḍamūlotkvathitam̐jvarātsaparīkartikāt.

Payo vimucyatepītā.....(Ca.Ci. 3: 235)

Fever- Intake of *Ricinus communis* (Castor-oil plant) root decoction is useful in treating fissure-in-ano associated with fever. [15] (Ca.Ci. 3:235)

Tato dāhetusañjātepatraireraṇḍasambhavaiḥ.

Śītalairdhāritairāṇḍedāham̐tasyāpanodayet. (Bhā.Pra.Ci. 1: 778)

Fever with chills- Covering up of the whole body with *Ricinus communis* (Castor-oil plant) leaves is useful in alleviating burning sensation caused due to fever associated with chills. [10] (Bh.Pr.Ci.1:778)

Śṛtameraṇḍamūlenabālabilvenavājvarāt.

Dhāroṣṇaṃvāpayahpītvāvibaddhānilavarcaṣaḥ.

Sarakṭapicchātisṛtaiḥsatṛṣṭūlapravāhikāt. (A.Hr.Ci. 1: 112)

Fever- Intake of the milk processed with *Ricinus communis* (Castor-oil plant) root helps in the expulsion of flatus, faecus and *Āma* associated disorders which results in the alleviation of fever, colic, dysentery and other diseases. ^[110] (As.Hr.Ci. 1:112)

Eraṇḍasyatupatrāṇilīptabhūmaunidhāpayet.

Dāhādijvariṇodehetānipatrāṇidhārayet.

Tena naśyatidāho'syajvaraścaivopaśāmyati.

Dāheśānteyadāśaityaṃtaccayuktyānivārayet. (Bhā.Pra.Ci. 1: 785-786)

Vāta associated inflammation- Drinking of *Ricinus communis* (Castor-oil plant) oil for 15 days or one month is useful in alleviating *Vāta* associated inflammation. ^[10](Bhā.Pra.Ci. 1: 785-786)

Eraṇḍobilvamūlaṃ ca bṛhatīkaṇṭakārikā.

Karañjaśacirabilvaścaśvadamṣṭrā ca samāṃśikā.

Lepo'yamsarpiṣāyuktovātaśvayathunāśanaḥ.

Eṣaevamṃyathālābhaṃpariṣekaḥsukhāvahaḥ. (Kā.Saṃ.Khilasthāna 17: 52-54)

External application of the paste prepared from equal quantity of *Ricinus communis* (Castor-oil plant), *Aegle marmelos* (Indian quince) root, *Pongamia pinnata* (Pongam oil tree), *Holoptelea integrifolia* (Indian elm) *Solanum indicum* (Indian night shade), *Solanum xanthocarpum* (Yellow berred night shade), and *Tribulus terrestris* (Puncture vine) mixed with *Ghṛta* (Clarified butter) and sprinkling done with the decoction prepared from the above said herbs is useful in alleviating *Vāta* associated inflammation. ^[20] (Kas.Sm.Khil.St.17:52-54)

Śvadamṣṭrairaṇḍamūlaṃ ca bilvamūlaṃmahauṣadham.

Purāṇamūlakaṃcaīṣāṃkvāthekṣīraṃvipācayet.

Kṣīrāvaśeṣamāhṛtyakālesaghr̥taśarkaram.

Yathāgnipācayedenamvātaśvayathunāśanam. (Kā.Saṃ.Khilasthāna 17: 55-57)

Decoction prepared from the mature root of *Tribulus terrestris* (Puncture vine), *Ricinus communis* (Castor-oil plant), *Aegle marmelos* (Indian quince) and *Zingiber officinale* (Dry ginger root) cooked with milk in a proper manner till the milk is left behind then mixed with *Ghṛta* (Clarified butter) and sugar and again cooked over the fire as Mṛdu (less cooked), Madhya (medium cooked) and Tīkṣṇa (strongly cooked) respectively. Intake of this *Ghṛta* (Clarified butter) is useful in alleviating *Vāta* associated inflammation. ^[20] (Kas.Sm.Khil.St.17:55-57)

Viḍvātaśaṅgepayasārasairvāprāgbhaktamadyādurubūkatailam. (Ca.Ci. 12:28)

Intake of *Ricinus communis* (Castor-oil plant) oil along with cow milk or meat juice before the meals is useful in alleviating obstructed flatus and faecal matter caused due to inflammatory diseases. ^[15] (Ca.Ci.12:28)

Eraṇḍatailampayasāgavāṃmūtreṇavāpibet.

Tenāsyadoṣaśeṣaścaśvayathuścanivarttate. (Kā.Saṃ.Khilasthāna 17: 57-58)

Intake of milk or cow urine along with *Ricinus communis* (Castor-oil plant) oil is useful in alleviating vitiated *doṣa*'s caused due to inflammation. ⁽⁹⁾ [20] (Kas.Sm.Khil.St.17:57-58)

Yadvorubūkamūlaṃmadhudigdhāṃsthāpyateniśāṃsakalām.

Tasya salilasyapānāñjaṭharevṛddhiḥsamaṃyāti.

(Bhā.Pra.Ci. 39: 25)(Vaṃ.Se.Medarogaḥ 23)

Obesity- *Ricinus communis* (Castor-oil plant) root soaked in honey regularly overnight, next day morning drinking of this juice is useful in treating obesity. ^[10] (Bh.Pr.Ci.39:25), ^[13] (Vg.Sn.Medo:23)

Kṣāravātāripatrasyahiṅguyuktaṃpibennaraḥ.

Medovṛddhivināśāyabhaktamaṇḍasamanvitam. (Vaṃ.Se.Medarogaḥ 19)

Drinking of *Ricinus communis* (Castor-oil plant) leaf decoction mixed with Yavaḥṣāra and *Ferula narthex* (Asafoetida) followed with the diet of cooked rice is useful in alleviating obesity. ^[13] (Vg.Sn.Medo:19)

Rejuvenation and virilification

Eraṇḍamūlaniṣkvāthomadhutailasasaindhavam.

Eṣayuktarathobastiḥsavacāpippalīphalaḥ. (Śā.Saṃ.U.Kha. 6: 50)

Rejuvenation- Enema of *Ricinus communis* (Castor-oil plant) root decoction mixed with honey, oil and rock salt along with *Acorus calamus* (Sweet flag), *Piper longum* (Long pepper) and *Randia spinosa* (Common emetic nut) powder as (Prakṣepa Dravya) is useful in promoting rejuvenating properties. ^[12] (Shr. Sm. Ut.Kh.6:50)

Parts Used

Root, leaf, flower, seed, oil.

Dose

Root-bark 10-20gm (for decoction), seed 2-6 grains, oil 10-20ml, leaf decoction 20-40ml, root decoction 20-40ml, powder 2-4gm or as directed by the physician.

Toxicity

It is contraindicated in intrinsic obstruction, abdominal pain, appendicitis, intrinsic inflammation. Its large doses may lead to abdominal pain, dermatological diseases, Udāvarta (abnormal movements of Vāyu), vomiting and other diseases. ^[21][HMH: 162]

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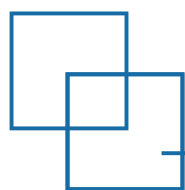
Abbreviation

A.Hṛ.Ci.	:	AṣṭāṅgaHṛdayaCikitsā
A.Hṛ.U.	:	AṣṭāṅgaHṛdaya Uttara Tantra
As.Hr.Ut.	:	AṣṭāṅgaHṛdaya Uttara Tantra
Bhā.Pra.Ci.	:	BhāvaprakśaCikitsā
Śā.Sa.Ut.Kha.	:	ŚāraṅgadharaSamhitā Uttara Khaṇḍa
Ca.Ci.	:	Caraka SamhitāCikitsāSthāna
Ca.Da.Ci.	:	CakradattaCikitsā
Ca.Si.	:	Caraka Samhitā Siddhi Sthāna
Ca.Sū.	:	Caraka SamhitāSūtraSthāna
Ck.Dt.Ci.	:	CakradattaCikitsā
Ga.Ni.Kā.Ci.	:	GadanigrahaKāyacikitsā
Ga.Ni.Kau.Taṃ.	:	GadanigrahaKaumaryatantra
Ga.Ni.Śā.Ta.	:	GadanigrahaŚālākya Tantra
Ga.Ni.Śa.Taṃ.	:	GadanigrahaŚalyatantra
Hā.Sa.	:	HārāitaSamhitā
Hā.Saṃ.	:	HārāitaSamhitā
Kā.Saṃ.Khilasthāna	:	KāśayapaSamhitāKhilasthāna
Rā.Mā.	:	RājaMārtaṇḍa
Ra.Ra.Sa.	:	Rasa Ratna Samuccaya
Śā.Ni.Guḍūcyādivarga	:	ŚāligrāmaNighaṇṭuGuḍūcyādivarga
Śā.Sa.U.Kha.	:	ŚāraṅgadharaSamhitā Uttara Khaṇḍa
Śā.Saṃ.Ma.Kha.	:	ŚāraṅgadharaSamhitā Madhyam Khaṇḍa
Sd.Bh.Mm. Ch. Gr.Ci.	:	Siddha BheṣajaMaṇimālāCaturthaGucchaGrahaṇāiCikitsā
Sd.Bh.Mm. Ch. Nd.Vr.Ci.	:	Siddha BheṣajaMaṇimālāCaturthaGuccha Nāḍāivraṇa Cikitsā
Sd.Bh.Mm. Ch.Nt.Rg.	:	Siddha BheṣajaMaṇimālāCaturthaGuccha Netra RogaCikitsā
Sd.Bh.Mm.Ch. Ars.Ci.	:	Siddha BheṣajaMaṇimālāCaturthaGucchaArśaCikitsā
Sd.Bh.Mm.Ch. Vrn.Ci.	:	Siddha BheṣajaMaṇimālāCaturthaGucchaVraṇaCikitsā
Sh.Gr.Ng. Gd.Vg.	:	ŚāligrāmaNighaṇṭuGuḍūcyādivarga
Su.Ci.	:	SuśrutaSamhitāCikitsāSthāna

Su.Ka.	:	SuśrutaSamhitā Kalpa Sthāna
Su.Śā.	:	SuśrutaSamhitāSārīraSthāna
Su.Ut.	:	SuśrutaSamhitā Uttara Tantra
Vai.Jī. Caturthavilāsa	:	Vaidya JāivanamCaturthavilāsa
Vai.Jī. Dvitīyavilāsaḥ	:	Vaidya JāivanamDvitīyavilāsaḥ
Vai.Ma.	:	Vaidya Manoramā
Vaṃ. Se. Āmavātarogādhikāraḥ	:	VaṃgasenaSamhitāĀmavātarogādhikāraḥ
Vaṃ.Se. Vātavyādhidhikāraḥ	:	VaṃgasenaSamhitāVātavyādhidhikāraḥ
Vaṃ.Se.Karṇarogaḥ	:	VaṃgasenaSamhitāKarṇarogādhikāraḥ
Vaṃ.Se.Medarogaḥ	:	VaṃgasenaSamhitāMedorogādhikāraḥ
Vaṃ.Se. Netrarog	:	VaṃgasenaSamhitāNetrarogādhikāra
Vaṃ.Se. Śothādhikāraḥ	:	VaṃgasenaSamhitāŚothādhikāraḥ
Vaṃ.Se. Strīrogaḥ	:	VaṃgasenaSamhitāStrīrogaḥ
Vaṃ.Se.Vātavyādhīḥ	:	VaṃgasenaSamhitāVātavyādhidhikāraḥ
Vṛ.Mā.	:	Vṛndamādhava

CHAPTER
01

Plant Exploration and Botanical Study



INTRODUCTION

Water is the key resource required to sustain life on this planet. It is found in most of the earth as in the ocean, rivers, ponds, streams, ice, etc. The river Ganga is an important source of water in India that makes an important river system from the Himalaya to the Bay of Bengal. The Indian civilization and economy depended on this river system due to its water availability throughout the year (Paul and Sinha, 2013). The river Ganga alone accounts for 25% of India's total water resources (Paul, 2017). Globally more than 300 million people from India, Nepal, and Bangladesh depend on the river Ganga (Gopal, 2000). This is the thirtieth longest river in the world and covers a basin area of 861,404 km² (Rahaman, 2009a). This basin is the most populated area in the world with an average density of 520 persons/km² (Das and Tamminga, 2012). The basin is very rich in heritage, cultural, and religious values. India's about one-fourth area drains by the river Ganga.

The river originates from the Gangotri glacier at Gomukh (30° 36' N; 79° 40' E; 3800 m) in the Uttar Kashi district of Uttarakhand under the name of Bhagirathi; and another tributary *i.e.*, Alaknanda which is originated from the Bhagirath-Kharak (30° 49' N; 79° 17' E) and Satopanth (30° 45' N; 79° 21' E) glaciers. Both the tributaries join at Devprayag from where the name Ganga started. The river has a total length of 2600 km from its main source Gomukh.

Up to Haridwar, it flows in the hills after here, it enters the plain area. From here, it flows southwards, passing through the plains of Uttar Pradesh starting from Bijnor district. Up to Ballia, it continuously flows in Uttar Pradesh through different districts after here, it enters Bihar near Chausa of Buxar district. It flows up to Katihar district in Bihar and from here it enters the Sahebganj district of Jharkhand. Then it turns southwards and enters West Bengal from the Murshidabad district. About 40 km from the Farakka, it divides into two streams; the left stream flows eastwards toward Bangladesh while the right stream, known as Bhagirathi, continues to flow south through West Bengal. Its name changed to Hooghly when it flows in the west and south-west of Kolkata. The Hooghly at Diamond Harbor flows southward and is split into two streams before reaching the Bay of Bengal (Rahaman, 2009b).



The annual water discharge from the river Ganga is about 18700 m³/s which is the fifth highest in the globe (Paul, 2017). The maximum flow of the Ganga exists within the catchment area with a mean maximum flow is 468.7×10^9 m³ which is a total of 25.2 % of the total water resources of India (Sarkar et al., 2012). The main source of the river Ganga is the melting of snow in the Himalayas and monsoon rains. The water of the Ganga is regularly used by the living being for drinking. Outdoor bathing has a spiritual significance for Hindus in which millions of people take a holy dip at least once a year throughout the course of the river, from Gangotri to Ganga Sagar.

The Ganga basin supports biodiversity, species richness, and uniqueness, attracting people from different parts of the earth. Plant communities have been a major magnetism for investigation since time immemorial. Vegetation composition and assemblages of an area form a significant habitat that contributes to the structure and function of such ecosystems. The vegetation pattern along the Ganga varies according to the seasonal changes, flood level, and species composition differs by the function of water supply and different soil types, which has a sharp influence on plant species distribution. Macrophytes such as submerged, emergent, and free-floating aquatic plants are known to accumulate and bioconcentrate heavy metals producing an internal concentration several folds greater than their surroundings (Allen-Diaz et al., 2008; Chen et al., 2008). The river basin has large numbers of medicinal plant species. The natives depend on the river for water and medicinal importance to fulfill their requirements from the beginning.

Among all the medicinal plants, *Ricinus communis* L. was considered in this study. It is commonly known as castor bean which is a tropical plant that grows all over the world (de Assis Junior et al., 2011). The plant is indigenous to India, where it is grown in fields and gardens as well as in untamed areas and waste places. *R. communis* is a little woody tree that grows to a height of approximately 6-8 meters. It may be found in Russia, Brazil, India, and South Africa. *Ricinus communis* stems have antiprotozoal, antidiabetic, and anticancer properties (Singh et al., 2010). The plant's leaves, roots, and seed oil are used in Indian medicine to treat liver problems, inflammation, hypoglycemia, and laxative effects (Kensa, 2012). Based on this, the morphology, taxonomy, anatomy, and distribution analysis of *R. communis* in the Ganga River basin are the main topics of this chapter.

Genus *Ricinus* L.

Ricinus is a member of the family Euphorbiaceae, which contains a vast number of plants mostly native to the tropics. The genus *Ricinus* is monotypic and *R. communis* is the only species, which includes many polymorphic types. These are dwarf annuals under cultivation. Thick horizontal roots make up the well-developed root system of castor plants. A tap root seems to be a stem extension that is buried in the ground. The stem is smooth, glabrous, erect, round in section, and has good branching. It is also slightly hollow. The stem has varying tints of red, green, or both colors. A leaf emerges from each of the well-defined nodes that identify the stem. The length of the lower internodes grows with height, and they are shorter. Large, palmate, alternating leaves with five to eleven lobes and acuminate edges that are notched, serrated, or indented. They are supported by lengthy, robust petioles. The primary and lateral branches bear the inflorescence terminally. The flowers are enormous, in terminal sub panicled racemes, monoecious, and apetalous, with the male flowers occupying the bottom section of the raceme and the female flowers occupying the upper portion.

Traditional medicine still makes extensive use of castor oil, which is extracted from the plant's seed. After the oil was removed, boiled to eliminate the toxicity, and added to animal feed, the plant's seed was used as fertilizer. Castor oil is primarily used as a laxative and purgative. In addition, it is used as a lubricant, lamp fuel, a component of cosmetics, and in the production of paints, varnishes, embalming fluid, textile dyes, leather finishes, adhesives, waxes, fungicides, soaps, printer's ink, plastics, fibers, hydraulic fluid, and braking fluid (Jena and Gupta, 2012).

Etymology

The genus is a member of the Euphorbiaceae family. The Latin term "*ricinus*," which means "tick", was given to the plant because of the seeds' apparent similarity to a specific kind of European tick (Salihu et al., 2014).

Species

Genus *Ricinus* is monotypic and *R. communis* L. in Sp. Pl.: 1007 (1753) is the only species (POWO, 2023; WFO, 2023).

Ricinus communis L.

R. communis is commonly known as castor oil plant which comes from its uses as a replacement for a perfume base made from dried perineal glands of beaver (Salihu et al., 2014). Although castor plants are generally accepted to be native to Africa, cultivation has spread the plant overall in tropical and subtropical regions as well as many temperate nations worldwide. The growth and look of castor plants vary widely. Its growth habits, the color of the leaf stems, the size and color of the seeds, and the oil content all differ, making variants difficult to compare. Large perennials that frequently grow into small trees may be found among castors; other varieties act like short-lived dwarf annuals, and there are variations in between. The terms giant and dwarf castor kinds, respectively, are often used to refer to the tree and short-internode types (Weiss, 1983). On the other hand, castor grows extraordinarily quickly if planted in full sun and given an abundance of fertilizer and water.

There are two varieties of castor plants: tall and short. The tall variety has significant laterals and secondary roots in addition to a huge, well-developed tap root that can reach several feet in length. Dwarf-type roots always exhibit less obvious taproots and are specific to a given variety or cultural system. Aerial development often occurs more slowly than root growth in dry regions when a plant's primary source of nutrition is rainwater. A robust root system enables a plant to benefit as much as possible from soil moisture, which plays a significant

role in the plant's ability to withstand drought. Because a root system enables a crop to properly accumulate biomass, it exhibits a high link with production by facilitating the absorption of essential nutrients and water. Castor plants benefit from adequate root growth, which will increase output when they are planted in soft, loose soil (Salihu et al., 2014).

A significant oilseed crop, castor has several uses in the medicinal, industrial, and agricultural industries. Between 40% and 60% of the seeds are made of oil. Its oil is distinct from other vegetable oils as it is the sole source of hydroxylated fatty acid available for purchase. Castor oil has special chemical and physical qualities due to the presence of hydroxyl groups and double bonds in ricinoleic acid, which makes the oil an essential industrial raw resource. One of the natural remedies for many illnesses is castor oil. Due to the active compounds, it is used extensively in the manufacturing of a variety of pharmaceutical and cosmetic goods (Salihu et al., 2014). Utilizing castor oil to produce biodiesel is theoretically possible. Because of its high energy value and advantageous fuel qualities, biodiesel made from castor oil has a notable benefit in terms of lubricity (Refaat, 2009; Berman et al., 2011).

Classification

Kingdom	-	Plantae
Subkingdom	-	Tracheobionta
Super Division	-	Spermatophyta

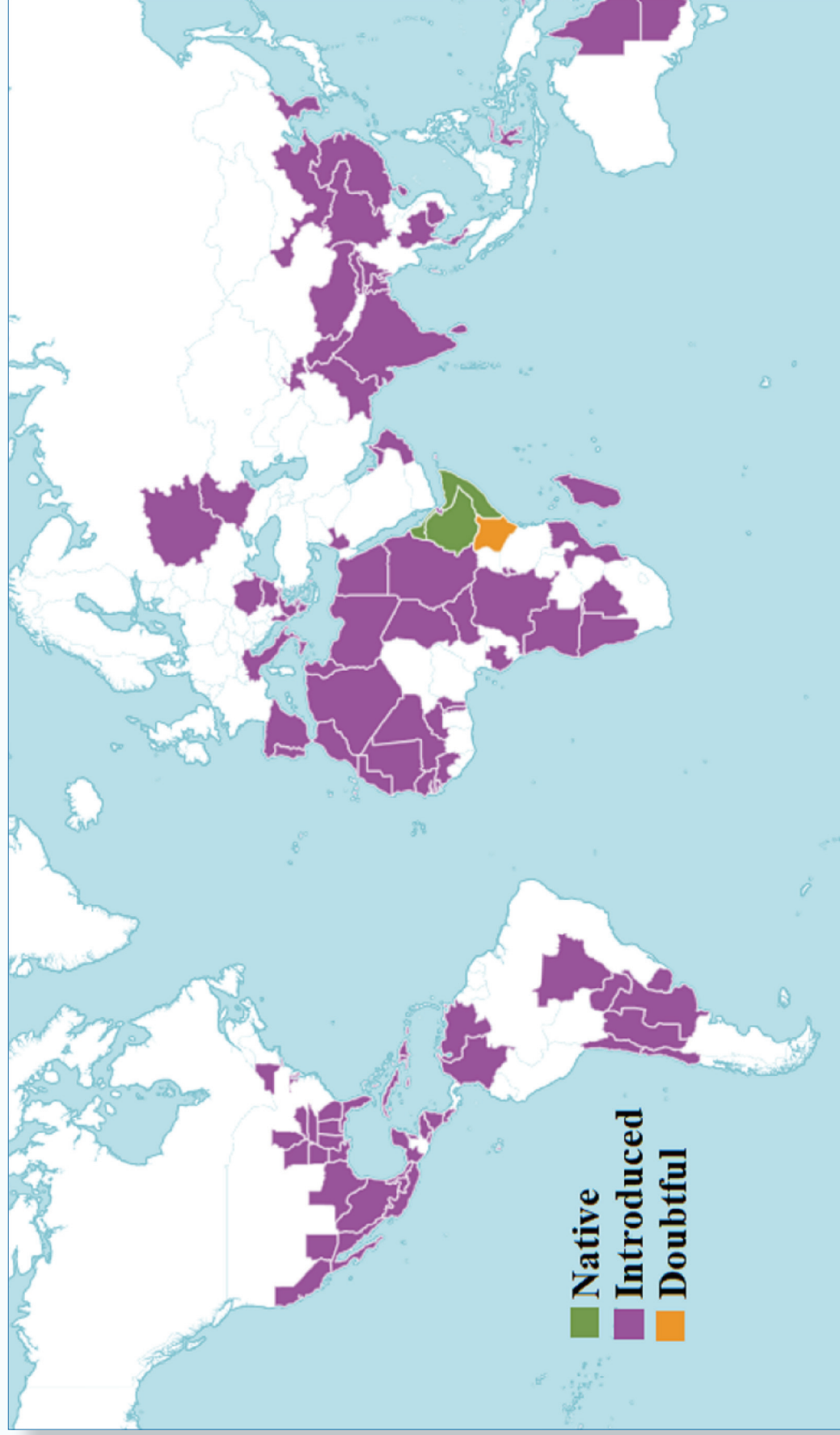


Fig. 1 Global distribution of *R. communis*

Division	-	Mangoliophyta
Class	-	Mangoliophsida
Order	-	Malpighiales
Family	-	Euphorbiaceae
Genus	-	<i>Ricinus</i>
Species	-	<i>communis</i>

Common Names

Castor bean, Castor oil plant (English); Wonder tree, Arandi (Hindi); Kege (Manipuri); Amanakku, Vilakkennai Kottaimuttu (Tamil); Oudla (Kannada); Veranda (Bengali); Era-gach (Assamese); Chittamankku (Malayalam).

Global Distribution

The natural habitat of this species is in northeastern tropical Africa. This tree or shrub is primarily found in the tropical biome, which is occasionally dry. It is mostly found in warm-temperate, tropical, and subtropical climates worldwide. In addition to being prevalent along seasonally dry rivers at elevations of 400 to 2700 m, it is also frequently found in fellow land, roadside, and compounds in urban as well as rural areas (Chakrabarty et al., 2021). According to POWO (2023), it is native to Eritrea, Ethiopia, Somalia; and introduced in Alabama, Albania, Algeria, Andaman Is., Angola, Argentina Northeast, Argentina Northwest, Arizona, Arkansas, Aruba, Ascension, Assam, Azores, Bahamas, Bangladesh, Belize, Benin, Bermuda, Bismarck Archipelago, Botswana, Brazil West-Central, Bulgaria, Burkina, Burundi, California, Cambodia, Canary Is., Caprivi Strip, Caroline

Is., Cayman Is., Central African Repu, Central American Pac, Central European Rus, Chad, Chagos Archipelago, Chile Central, Chile North, China North-Central, China South-Central, China Southeast, Christmas Is., Cocos (Keeling) Is., Colombia, Comoros, Cook Is., Costa Rica, Cuba, Djibouti, Dominican Republic, East Aegean Is., East Himalaya, Easter Is., Egypt, El Salvador, Fiji, Florida, Gabon, Galápagos, Gambia, Georgia, Gilbert Is., Greece, Guinea, Guinea-Bissau, Gulf of Guinea Is., Gulf States, Hainan, Haiti, Hawaii, Honduras, Illinois, India, Italy, Jamaica, Juan Fernández Is., Kazan-retto, Kentucky, Kermadec Is., Korea, Leeward Is., Libya, Louisiana, Madagascar, Madeira, Maldives, Mali, Marianas, Marquesas, Marshall Is., Maryland, Mauritania, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Mississippi, Missouri, Morocco, Mozambique, Mozambique Channel Is., Namibia, Nauru, Netherlands Antilles, New Caledonia, New South Wales, New York, New Zealand North, Nicaragua, Nicobar Is., Niue, Norfolk Is., Ogasawara-shoto, Oman, Pakistan, Palestine, Paraguay, Pitcairn Is., Portugal, Puerto Rico, Queensland, Romania, Rwanda, Samoa, Selvagens, Senegal, Sicilia, Society Is., Socotra, South China Sea, South European Russi, Southwest Caribbean, Spain, Sri Lanka, St.Helena, Sudan, Sulawesi, Tadzhikistan, Tennessee, Texas, Thailand, Tibet, Togo, Tonga, Trinidad-Tobago, Tuamotu, Tubuai Is., Tunisia, Uruguay, Vanuatu, Venezuela, Venezuelan Antilles, Wake Is., Wallis-Futuna Is., West Himalaya, Western Sahara, Windward Is., Zaire; while it is doubtful in Kenya (Fig. 1).

Distribution in India

India is also one of the origin centers because of the great natural diversity of castor that is found there. It is a weed that grows on the banks of creeks, dry riverbeds, canals, roadsides, railroads, disturbed sites, pastures, gardens, abandoned suburban areas, and other waste spots across tropical, subtropical, temperate, and sometimes semi-arid parts of India.

Ethnobotany and Traditional Uses

It has long been known that castor beans are extremely poisonous. Farmers have long since realized that they run the risk of losing their livestock if they let them go too close to the castor plant. Its seeds have been used by traditional medicine to cure a wide variety of ailments. The possible health advantages of castor bean seed proteins have been researched since antiquity. Later, it was demonstrated that they had a major impact on the early phases of immunological research and the identification of several fundamental immunological concepts. Over the past thirty years, the poisons' mode of action has been clarified. This prompted significant efforts to direct the poisons towards cancerous cells. Additionally, ricin has been utilized in bioterrorism (Polito et al., 2019).

Castor oil is frequently used for lubrication, lighting, and catharsis. The oil is widely used in industry, either in its original form or after modifications. Most commercial oil is treated in many ways and then utilized for

various applications. The treated oil is used in a variety of products, including enamels, nitrocellulose-baking finishes, paints, and varnishes; fly paper; greases, waxes, and special lubricants; linoleum; oiled fabrics; patent leather; polishes, typewriting, and printing inks; condenser, cutting, and dielectric oils; urethane foams and rubber substitutes; pharmaceuticals; cosmetics; and insecticidal formulations (Rana et al., 2012). While oil from the annual forms is favored for therapeutic purposes, oil from the perennial species is utilized for lubrication and lighting. When pregnant women reach term, castor oil is frequently administered orally, either by itself or in combination with quinine sulfate. Parenteral steroidal hormone delivery can be carried out using oil (Rana et al., 2012).

India has been using it in lamps since ancient times since it is a great illuminant. It is used in the production of soap (National Institute of Science Communication Resource, 1972). Castor oil is primarily used as a laxative and purgative (Jena and Gupta, 2012). Since ancient times, castor oil has been widely used as a curative agent in traditional medicines all over the world for a variety of illnesses, including chronic headaches, constipation, gallbladder pain, insomnia, menstrual cramps, period pain, placenta expulsion, rheumatism, sciatica, and sleeplessness (Khan Marwat et al., 2017). Suitable for babies and young children, the puerperal state, and irritable disorders of the alimentary canal or genitourinary organs, castor oil is a moderate and highly effective purgative.

Additionally, the leaves have been suggested for application to women's breasts to stimulate milk production as a decoction or poultice (Rana et al., 2012). Its fruit extract is a strong candidate for the treatment of breast cancer (Majumder et al., 2019; Chouhan et al., 2021). When taken internally, the decoction is also said to have lactagogue and emmenagogue properties (Bentley and Trimen, 2007). In India, castor cake is used as manure. It is a good manure for rice, sugarcane, tobacco, and other plants since it is high in nitrogen and other minerals. Sometimes cattle are fed leaves. They are said to boost milk production. Aphids, mosquitoes, white flies, and rust mites are all kept at bay by using the powdered leaves (Rana et al., 2012).

It is stated that leaves are used topically for wounds, boils, and swellings as a poultice. Children with flatulence can often get relief from it by applying heated, oil-coated leaves to their abdomen. A leaf infusion is applied topically as an eye ointment and for stomachaches (Khan Marwat et al., 2017). Ground leaves are placed on guinea worm wounds to draw out the worm and are believed to relieve dental cavities. According to reports, fresh leaf juice may be used as an emetic for opium overdose and is also beneficial for jaundice. For lumbago and related problems, roots are taken as a decoction; for toothaches, they are used as a paste. It is said that the root bark has strong purgative properties (Rana et al., 2012).

Phytochemical Constituents

Plants include several important phytochemicals, including steroids, saponins, alkaloids, flavonoids, and glycosides. The alkaloids like ricinine and N-demethylricinine and flavones glycosides like kaempferol-3-O-kaempferol-3-O- β -D-glucopyranoside, quercetin-3-O- β -D-xylopyranoside, quercetin-3-O- β -D-glucopyranoside, kaempferol O- β -rutoside, and quercetin-3-O- β -rutoside are the major phytochemicals have been reported from the leaves (Kang et al., 1985). Ellagic acid, epicatechin, gallic acid, gentisic acid, quercetin, and rutin are the main phenolic compounds that have been extracted from leaves. The monoterpenoids include 1,8-cineole, camphor, α -pinene; the sesquiterpenoid is β -caryophyllene. The roots have been processed to extract indole-3-acetic acid (Darmanin et al., 2009; Singh et al., 2009). About half of the seeds' weight is made up of oil, which contains ricinine, lipases, a crystalline alkaloid, and glycosides of ricinoleic, isoricinoleic, stearic, and dihydroxystearic acids (Khogali et al., 1992). An investigation revealed the existence of ester derived from dihydroxy, arachidic acids, hexadecenoic, palmitic, ricinoleic, and stearic acids (Kang et al., 1985). The stem of this plant contains ricin, one of its main constituents (Jena and Gupta, 2012). Probucol, γ -sitosterol, fucosterol, stigmasterol, and ergost-5-en-3-ol were all detected in the seed ether extract. GC-MS examinations of oil have discovered many additional chemicals, including

α -thujone, camphor, α -pinene, 1,8-cineole, and camphene (Kadri et al., 2011).

Selection of the Sites and Characteristics Studied

The distribution, morphological variations, and association of *R. communis* were investigated across the Ganga River. The Ganga began from the Gomukh in Gangotri glacier and ended at Gangasagar in the Bay of Bengal. A total of twenty-six sites were selected with

two sites ranging around 100 km in distance while the whole distance is about 2600 km (Table 1). The plant diversity was assessed up to the 10 km on both sides of each site. The plants were identified and deposited in the Patanjali Research Foundation Herbarium with an acronym of PRFH for future records. A bulk sample of the plant was taken from each site in a large polybag which was deposited in the analytical laboratory for phytochemical profiling.

Table 1 Different studied sites and their GPS coordinates along with *R. communis* Status

Site	Locality	GPS Coordinates			Status
		Altitude (m)	Latitude (N)	Longitude (E)	
S1	Gomukh	4023	30.80	79.15	Absent
S2	Gangotri	3415	30.98	78.93	Absent
S3	Uttarkashi	1158	30.73	78.44	Absent
S4	Devprayag	830	30.15	78.60	Present
S5	Haridwar	314	29.97	78.17	Present
S6	Bijnor	225	29.37	78.13	Present
S7	Narora	174	28.20	78.38	Present
S8	Budaun	164	28.05	79.12	Present
S9	Farrukhabad	151	27.37	79.63	Present
S10	Bithoor	126	26.61	80.27	Present
S11	Dalmau	115	26.07	81.03	Present
S12	Prayagraj	98	25.45	81.85	Present
S13	Mirzapur	80	25.15	82.58	Present
S14	Varanasi	81	25.32	83.01	Present
S15	Ballia	67	25.76	84.15	Present
S16	Revelganj	52	25.78	84.67	Present
S17	Patna	53	25.61	85.14	Present
S18	Barh	47	25.48	85.72	Present

Site	Locality	GPS Coordinates			Status
		Altitude (m)	Latitude (N)	Longitude (E)	
S19	Bahachouki	55	25.30	86.36	Present
S20	Farka	42	25.23	87.09	Present
S21	Sahebganj	16	25.25	87.65	Present
S22	Farakka Bar- rage	30	24.82	87.90	Absent
S23	Murshidabad	18	24.18	88.27	Absent
S24	Mayapur	11	23.43	88.39	Absent
S25	Hoogli	9	22.91	88.40	Present
S26	Gangasagar	4	22.19	88.19	Absent

Local Occurrence

The plant was collected for the analytical studies only from sites 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 25, due to these sites being the source of its bulk collection. For the remaining sites, namely, 1, 2, 22, 23, 24, and 26, it was either absent or rarely found.

Taxonomic Treatment

Ricinus communis L. Sp. Pl.: 1007. 1753; Hook.f., Fl. Brit. India 5: 457. 1885; Duthie, Fl. Gangetic Plain 3: 113. 1915; Haines, Bot. Bihar Orissa (Repr. ed.) 1: 116. 1961; Uniyal & al., Fl. Pl. Uttarakhand, Checkl.: 217. 2007; Sinha & Sukla, Fl. Uttar Pradesh 2: 456. 2020.

Synonyms

The Plants of the World Online database mentioned it with its 2 homotypic and 211 heterotypic synonyms (POWO, 2023) as

Homotypic Synonyms

1. *R. communis* var. *genuinus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866), not validly publ.
2. *R. communis* var. *typicus* Fiori in A.Fiori & al., Fl. Anal. Italia 2: 292 (1901), not validly publ.

Heterotypic Synonyms

1. *Cataputia major* Ludw. in Ectypa Veg.: t. 7 (1760)
2. *C. minor* Ludw. in Defin. Gen. Pl., ed. 3.: 81 (1760)
3. *Croton spinosus* L. in Sp. Pl.: 1005 (1753)
4. *Ricinus africanus* Mill. in Gard. Dict., ed. 8.: n.º 5 (1768)
5. *R. angulatus* Thunb. in Ricin.: 6 (1815)
6. *R. armatus* Andrews in Bot. Repos. 6: t. 430 (1805)
7. *R. atropurpureus* Pax & K.Hoffm. in H.G.A.Engler (ed.), Pflanzenr., IV, 147, IX: 126 (1919)

8. *R. badius* Rchb. in Iconogr. Bot. Exot. 2: 21 (1829)
9. *R. borboniensis* Pax & K.Hoffm. in H.G.A.Engler (ed.), Pflanzenr., IV, 147, IX: 126 (1919)
10. *R. cambodgensis* Benary in Gartenflora 36: 102 (1887)
11. *R. communis* var. *aegyptiaceus* (Popova) Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 40 (1980)
12. *R. communis* subsp. *africanus* (Mill.) Nyman in Consp. Fl. Eur.: 647 (1881)
13. *R. communis* var. *africanus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866)
14. *R. communis* subvar. *almeidae* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 58 (1956)
15. *R. communis* var. *amblyocalyx* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866)
16. *R. communis* f. *americanus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1017 (1866)
17. *R. communis* subvar. *americanus* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 44 (1956)
18. *R. communis* var. *americanus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1017 (1866)
19. *R. communis* f. *argentatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 34 (1956)
20. *R. communis* f. *argyratus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 36 (1956)
21. *R. communis* var. *armatus* (Andrews) Steud. in Nomencl. Bot., ed. 2, 2: 459 (1841)
22. *R. communis* f. *atratus* T.Carvalho in Anais Junta Invest. Ultramar 11(2): 32 (1956)
23. *R. communis* f. *atrobrunneatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 37 (1956)
24. *R. communis* f. *atrofulvatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 55 (1956)
25. *R. communis* f. *atrofuscatatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 53 (1956)
26. *R. communis* f. *atrophoeniceus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 66 (1956)
27. *R. communis* f. *atropunicatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 43 (1956)
28. *R. communis* f. *atropurpureatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 50 (1956)
29. *R. communis* f. *avellanatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 56 (1956)
30. *R. communis* var. *badius* (Rchb.) Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866)
31. *R. communis* var. *bailundensis* J.M.Coult. in Bull. Soc. Portug. Sci. Nat. 1918: 82 (1918)
32. *R. communis* var. *benguelensis* Müll.Arg.

- in J. Bot. 1: 337 (1864)
33. *R. communis* subvar. *blumeanus* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 46 (1956)
 34. *R. communis* f. *blumeanus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
 35. *R. communis* var. *borboniensis* André in Pl. Feuill. Ornem.: 206 (1866)
 36. *R. communis* var. *brasiliensis* Müll.Arg. in C.F.P.von Martius & auct. suc. (eds.), Fl. Bras. 11(2): 421 (1874)
 37. *R. communis* var. *brevinodis* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 32 (1980)
 38. *R. communis* var. *caesius* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 287 (1941)
 39. *R. communis* f. *canatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 47 (1956)
 40. *R. communis* f. *canescens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 48 (1956)
 41. *R. communis* f. *carneatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 44 (1956)
 42. *R. communis* f. *cervatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 43 (1956)
 43. *R. communis* f. *cinerascens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 27 (1956)
 44. *R. communis* f. *cinereatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 65 (1956)
 45. *R. communis* f. *denudatus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
 46. *R. communis* f. *epiglaucus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
 47. *R. communis* subvar. *epruinosis* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 43 (1956)
 48. *R. communis* f. *erythrocladus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
 49. *R. communis* subvar. *erythrocladus* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 64 (1956)
 50. *R. communis* f. *exiguus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 68 (1956)
 51. *R. communis* f. *fulvatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 68 (1956)
 52. *R. communis* f. *fumatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 41 (1956)
 53. *R. communis* f. *fuscatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 35 (1956)
 54. *R. communis* var. *giganteus* André in Pl. Feuill. Ornem.: 206 (1866)
 55. *R. communis* f. *gilvus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 53 (1956)
 56. *R. communis* subvar. *glaucus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 27 (1956)
 57. *R. communis* var. *glaucus* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 37 (1980)

58. *R. communis* f. *glaucus* (Hoffmanns.) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
59. *R. communis* f. *gracilis* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1021 (1866)
60. *R. communis* subvar. *gracilis* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 68 (1956)
61. *R. communis* var. *griseofolius* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 36 (1980)
62. *R. communis* subvar. *griseus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 33 (1956)
63. *R. communis* f. *guttatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 47 (1956)
64. *R. communis* f. *hybridus* (Besser) Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
65. *R. communis* var. *hybridus* (Besser) Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
66. *R. communis* f. *incarnatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 46 (1956)
67. *R. communis* var. *indehiscens* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 33 (1980)
68. *R. communis* subsp. *indicus* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 35 (1980)
69. *R. communis* f. *inermis* (Mill.) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
70. *R. communis* var. *inermis* (Mill.) Pax & K.Hoffm. in H.G.A.Engler (ed.), Pflanzenr., IV, 147, XI: 122 (1919)
71. *R. communis* f. *intermedius* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
72. *R. communis* var. *japonicus* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 35 (1980)
73. *R. communis* var. *krappa* Steud. in Nomencl. Bot., ed. 2, 2: 459 (1841), nom. nud.
74. *R. communis* f. *laevis* (DC.) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1021 (1866)
75. *R. communis* var. *leucocarpus* (Bertol.) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
76. *R. communis* var. *lividus* (Jacq.) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
77. *R. communis* var. *macrocarpus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 27 (1956)
78. *R. communis* subvar. *macrophyllus* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 64 (1956)
79. *R. communis* f. *macrophyllus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
80. *R. communis* var. *macrophyllus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
81. *R. communis* f. *maculatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 29 (1956)

82. *R. communis* subsp. *manshuricus* V.Bork. in Descr. Var. Azcherkaya: 106 (1936) Anais Junta Invest. Ultramar 11(4): 45 (1956)
83. *R. communis* f. *marmoreatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 40 (1956)
84. *R. communis* var. *megalospermus* (Delile) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1017 (1866)
85. *R. communis* var. *mexicanus* (Popova) Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 40 (1980)
86. *R. communis* subsp. *mexicanus* Popova in Bukasov S.M. Vozdelyv. Rast. Meksiki: 409 (1931)
87. *R. communis* subsp. *mexicanus* Popova in Bukasov S.M. Vozdelyv. Rast. Meksiki: 409 (1931)
88. *R. communis* var. *microcarpus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
89. *R. communis* var. *microspermus* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 31 (1980)
90. *R. communis* var. *minor* (Mill.) Steud. in Nomencl. Bot., ed. 2, 2: 459 (1841)
91. *R. communis* f. *murinatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 66 (1956)
92. *R. communis* var. *nanus* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 38 (1980)
93. *R. communis* f. *nigellus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 51 (1956)
94. *R. communis* f. *nigrescens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 45 (1956)
95. *R. communis* f. *niveatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 39 (1956)
96. *R. communis* f. *oblongus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 31 (1956)
97. *R. communis* f. *obscurus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 42 (1956)
98. *R. communis* f. *oligacanthus* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
99. *R. communis* f. *ostrinatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 58 (1956)
100. *R. communis* f. *pardalinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 31 (1956)
101. *R. communis* subsp. *persicus* Popova in Kleshchevina izd. VIR: 27 (1930)
102. *R. communis* proles *persicus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 289 (1941)
103. *R. communis* f. *picturatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 30 (1956)
104. *R. communis* f. *plumbeatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 62 (1956)
105. *R. communis* f. *pruinusosus* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1017 (1866)
106. *R. communis* subvar. *pruinusosus* (Müll. Arg.) T.Carvalho in Anais Junta Invest.

- Ultramar 11(4): 41 (1956)
107. *R. communis* f. *pullatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 49 (1956)
108. *R. communis* f. *punctatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 48 (1956)
109. *R. communis* f. *punctulatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 61 (1956)
110. *R. communis* f. *punicans* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 57 (1956)
111. *R. communis* f. *purpurascens* (Bertol.) Pax in H.G.A.Engler (ed.), Pflanzenr., IV, 147, XI: 122 (1919)
112. *R. communis* var. *purpurascens* (Bertol.) Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
113. *R. communis* subvar. *purpurascens* (Bertol.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 50 (1956)
114. *R. communis* f. *radiatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 64 (1956)
115. *R. communis* var. *reichenbachianus* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866)
116. *R. communis* var. *rheedianus* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
117. *R. communis* var. *roseus* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 31 (1980)
118. *R. communis* subvar. *roseus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 55 (1956)
119. *R. communis* var. *rubescens* Herder in Index Seminum (LE, Petropolitanus) 1868: 91 (1869)
120. *R. communis* subsp. *ruderalis* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 38 (1980), nom. illeg.
121. *R. communis* f. *rufescens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 55 (1956)
122. *R. communis* var. *rugosus* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
123. *R. communis* f. *russatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 57 (1956)
124. *R. communis* f. *rutilans* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1017 (1866)
125. *R. communis* subvar. *rutilans* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 40 (1956)
126. *R. communis* subsp. *sanguineus* Popova in Kleshchevina izd. VIR: 35 (1930)
127. *R. communis* var. *sanguineus* Baill. in Recueil Observ. Bot. 1: 342 (1861)
128. *R. communis* subsp. *scaber* (Bertol. ex Moris) Nyman in Consp. Fl. Eur.: 647 (1881)
129. *R. communis* f. *scaber* (Bertol. ex Moris) Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866)
130. *R. communis* f. *scriptus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 59 (1956)
131. *R. communis* subsp. *sinensis* Hiltebr. in

- Mirov. Rast. Res.: 63 (1935) (1956)
132. *R. communis* subsp. *sinensis* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 34 (1980), nom. illeg.
 133. *R. communis* f. *sordidus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 33 (1956)
 134. *R. communis* var. *speciosus* (Burm.f.) Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1021 (1866)
 135. *R. communis* var. *spontaneus* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 39 (1980)
 136. *R. communis* f. *stigmatosus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 28 (1956)
 137. *R. communis* f. *striatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 63 (1956)
 138. *R. communis* f. *subpurpurascens* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
 139. *R. communis* var. *subpurpurascens* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
 140. *R. communis* f. *subrotundus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 54 (1956)
 141. *R. communis* subvar. *subviridis* (Müll. Arg.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 65 (1956)
 142. *R. communis* f. *subviridis* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1019 (1866)
 143. *R. communis* f. *sulcatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 38 (1956)
 144. *R. communis* f. *tigrinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 39 (1956)
 145. *R. communis* f. *umbrinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 59 (1956)
 146. *R. communis* var. *undulatus* (Besser) Steud. in Nomencl. Bot., ed. 2, 2: 459 (1841)
 147. *R. communis* var. *vasconcellosii* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 33 (1956)
 148. *R. communis* f. *venosus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 37 (1956)
 149. *R. communis* f. *vinatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 52 (1956)
 150. *R. communis* var. *violaceocaulis* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 34 (1980)
 151. *R. communis* subvar. *violaceus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 36 (1956)
 152. *R. communis* subvar. *violeus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 30 (1956)
 153. *R. communis* var. *virens* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 290 (1941)
 154. *R. communis* var. *viridis* Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 32 (1980)
 155. *R. communis* f. *viridis* (Willd.) Müll.Arg.

- in A.P.de Candolle, Prodr. 15(2): 1020 (1866)
156. *R. communis* subvar. *viridus* (Willd.) T.Carvalho in Anais Junta Invest. Ultramar 11(4): 67 (1956)
157. *R. communis* subsp. *zanzibarinus* Popova in Kleshchevina izd. VIR: 43 (1930)
158. *R. communis* f. *zebrinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 60 (1956)
159. *R. communis* f. *zollingeri* Müll. Arg. in A.P.de Candolle, Prodr. 15(2): 1018 (1866)
160. *R. communis* f. *zonatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 50 (1956)
161. *R. compactus* Huber in Cat. Print. 1865: 8 (1865)
162. *R. digitatus* Noronha in Verh. Batav. Genootsch. Kunsten 5(4): 26 (1790), nom. nud.
163. *R. europaeus* T.Nees in Gen. Fl. Germ.: 38 (1833)
164. *R. gibsonii* H.J.Veitch in Gard. Chron., n.s., 2: 610 (1874)
165. *R. giganteus* Pax & K.Hoffm. in H.G.A.Engler (ed.), Pflanzenr., IV, 147, IX: 126 (1919)
166. *R. glaucus* Hoffmanns. in Verz. Pfl. Nachtr. 2: 199 (1826)
167. *R. hybridus* Besser in Cat. Jard. Bot. Krzemieniec, Suppl. 2: 13 (1814)
168. *R. inermis* Mill. in Gard. Dict., ed. 8.: n.º 6 (1768)
169. *R. japonicus* Thunb. in Ricin.: 4 (1815)
170. *R. krappa* Steud. in Nomencl. Bot., ed. 2, 2: 459 (1841), not validly publ.
171. *R. laevis* DC. in Rapp. [Not.] Pl. Rar. Genève 1: 31 (1823)
172. *R. leucocarpus* Bertol. in Giorn. Arcadico Sci. 21: 192 (1824)
173. *R. lividus* Jacq. in Misc. Austriac. 2: 360 (1781)
174. *R. macrocarpus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 278 (1941)
175. *R. macrocarpus* proles *indicus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 283 (1941)
176. *R. macrocarpus* proles *japonicus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 285 (1941)
177. *R. macrocarpus* var. *nudus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 287 (1941)
178. *R. macrocarpus* proles *sanguineus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 280 (1941)
179. *R. macrophyllus* Bertol. in Giorn. Arcadico Sci. 21: 192 (1824)
180. *R. medicus* Forssk. in Fl. Aegypt.-Arab.: 164 (1775)
181. *R. medius* J.F.Gmel. in Syst. Nat., ed. 13[bis].: 1615 (1792)
182. *R. megalosperma* Delile in F.Cailliaud, Voy. Méroé 4: 89 (1827)
183. *R. messeniacus* Heldr. in Exsicc. (Herb. Graec. Norm.) 15: n.º 1480 (1899)
184. *R. metallicus* Pax & K.Hoffm. in H.G.A.Engler (ed.), Pflanzenr., IV, 147, IX: 126 (1919)
185. *R. microcarpus* Popova in E.V.Wulff (ed.),

- Kul't. Fl. SSSR 7: 287 (1941)
186. *R. microcarpus* proles *aegypticus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 291 (1941)
 187. *R. microcarpus* var. *atrovirens* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 290 (1941)
 188. *R. microcarpus* proles *indostanicus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 290 (1941)
 189. *R. microcarpus* var. *spontaneus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 288 (1941)
 190. *R. minor* Mill. in Gard. Dict., ed. 8.: n.º 7 (1768)
 191. *R. nanus* Balb. in Cat. Stirp. (1813): 65 (1813)
 192. *R. obermannii* Groenland in Rev. Hort. (Paris), sér. 4, 7: 601 (1858)
 193. *R. peltatus* Noronha in Verh. Batav. Genootsch. Kunsten 5(4): 2 (1790), nom. nud.
 194. *R. perennis* Steud. in Nomencl. Bot., ed. 2, 2: 459 (1841)
 195. *R. persicus* Popova in Trudy Byuro Evgen. 16: 229 (1926)
 196. *R. purpurascens* Bertol. in Misc. Bot. 9: 4 (1851)
 197. *R. ruber* Miq. in Fl. Ned. Ind. 1(2): 390 (1859)
 198. *R. rugosus* Mill. in Gard. Dict., ed. 8.: n.º 4 (1768)
 199. *R. rutilans* Müll.Arg. in A.P.de Candolle, Prodr. 15(2): 1017 (1866)
 200. *R. sanguineus* Groenland in Rev. Hort. (Paris), sér. 4, 7: 601 (1858)
 201. *R. scaber* Bertol. ex Moris in Stirp. Sard. Elench. 1: 41 (1827)
 202. *R. speciosus* Burm.f. in Fl. Indica: 207 (1768)
 203. *R. spectabilis* Blume in Bijdr. Fl. Ned. Ind.: 623 (1826)
 204. *R. tunisensis* Desf. in Tabl. École Bot., ed. 3: 340 (1829)
 205. *R. undulatus* Besser in Cat. Jard. Bot. Krzemieniec: 90 (1811)
 206. *R. urens* Mill. in Gard. Dict., ed. 8.: n.º 3 (1768)
 207. *R. viridis* Willd. in Sp. Pl., ed. 4. 4: 564 (1805)
 208. *R. vulgaris* Garsault in Fig. Pl. Méd.: 66 (1764), opus utique oppr.
 209. *R. vulgaris* Mill. in Gard. Dict., ed. 8.: n.º 1 (1768)
 210. *R. zanzibarensis* Anon. in Ill. Hort. 41: 99 (1894)
 211. *R. zanzibarinus* Popova in E.V.Wulff (ed.), Kul't. Fl. SSSR 7: 292 (1941)
- While another database i.e., World Flora Online (WFO, 2023) mentioned it with a total of following 186 synonyms-
1. *Cataputia major* Ludw in Ectypa Veg.: t. 7 (1760)
 2. *C. minor* Ludw in Defin. Gen. Pl. ed. 3: 81 (1760)
 3. *Croton spinosus* L in Sp. Pl.: 1005 (1753)
 4. *Ricinus africanus* Mill in Gard. Dict. ed. 8: n.º 5 (1768)
 5. *R. angulatus* Thunb in Ricin.: 6 (1815)

6. *R. armatus* Andrews in Bot. Repos. 6: t. 430 (1805)
7. *R. atropurpureus* hort. ex Pax & K.Hoffm in Pflanzenr. , IV, 147, IX: 126 (1919)
8. *R. badius* Rchb in Iconogr. Bot. Exot. 2: 21 (1829)
9. *R. borboniensis* hort. ex Pax & K.Hoffm in Pflanzenr. , IV, 147, IX: 126 (1919)
10. *R. cambodgensis* Benary in Gartenflora 36: 102 (1887)
11. *R. communis* f. *americanus* Müll.Arg in Prodr. 15(2): 1017 1866
12. *R. communis* f. *argentatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 34 1956
13. *R. communis* f. *argyratus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 36 1956
14. *R. communis* f. *atratus* T.Carvalho in Anais Junta Invest. Ultramar 11(2): 32 1956
15. *R. communis* f. *atrobrunneatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 37 1956
16. *R. communis* f. *atrofulvatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 55 1956
17. *R. communis* f. *atrofuscatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 53 1956
18. *R. communis* f. *atrophoeniceus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 66 1956
19. *R. communis* f. *atropunicatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 43 1956
20. *R. communis* f. *atropurpureatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 50 1956
21. *R. communis* f. *avellanatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 56 1956
22. *R. communis* f. *blumeanus* Müll.Arg in Prodr. 15(2): 1018 1866
23. *R. communis* f. *canatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 47 1956
24. *R. communis* f. *canescens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 48 1956
25. *R. communis* f. *carneatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 44 1956
26. *R. communis* f. *cervatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 43 1956
27. *R. communis* f. *cinerascens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 27 1956
28. *R. communis* f. *cinereatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 65 1956
29. *R. communis* f. *denudatus* Müll.Arg in Prodr. 15(2): 1020 1866
30. *R. communis* f. *epiglaucus* Müll.Arg in Prodr. 15(2): 1020 1866
31. *R. communis* f. *erythrocladus* Müll.Arg in Prodr. 15(2): 1020 1866
32. *R. communis* f. *exiguus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 68

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33. *R. communis* f. *fulvatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 68 1956
 34. *R. communis* f. *fumatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 41 1956
 35. *R. communis* f. *fuscatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 35 1956
 36. *R. communis* f. *gilvus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 53 1956
 37. *R. communis* f. *glaucus* (Hoffmanns.) Müll.Arg in Prodr. 15(2): 1020 (1866)
 38. *R. communis* f. *gracilis* Müll.Arg in Prodr. 15(2): 1021 1866
 39. *R. communis* f. *guttatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 47 1956
 40. *R. communis* f. *hybridus* (Besser) Müll. Arg in Prodr. 15(2): 1020 1866
 41. *R. communis* f. *incarnatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 46 1956
 42. *R. communis* f. *inermis* (Mill.) Müll.Arg in Prodr. 15(2): 1018 1866
 43. *R. communis* f. *intermedius* Müll.Arg in Prodr. 15(2): 1020 1866
 44. *R. communis* f. *laevis* (DC.) Müll.Arg Prodr. 15(2): 1021 1866
 45. *R. communis* f. *macrophyllus* Müll.Arg in Prodr. 15(2): 1020 1866
 46. *R. communis* f. *maculatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 29 1956
 47. *R. communis* f. *marmoreatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 40 1956
 48. *R. communis* f. *murinatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 66 1956
 49. *R. communis* f. *nigellus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 51 1956
 50. *R. communis* f. *nigrescens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 45 1956
 51. *R. communis* f. *niveatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 39 1956
 52. *R. communis* f. *oblongus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 31 1956
 53. *R. communis* f. *obscurus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 42 1956
 54. *R. communis* f. *oligacanthus* Müll.Arg in Prodr. 15(2): 1020 1866
 55. *R. communis* f. *ostrinatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 58 1956
 56. *R. communis* f. *pardalinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 31 1956
 57. *R. communis* f. *picturatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 30 1956
 58. *R. communis* f. *plumbeatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 62 1956

59. *R. communis* f. *pruinus* Müll.Arg in Prodr. 15(2): 1017 1866
60. *R. communis* f. *pullatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 49 1956
61. *R. communis* f. *punctatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 48 1956
62. *R. communis* f. *punctulatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 61 1956
63. *R. communis* f. *punicans* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 57 1956
64. *R. communis* f. *purpurascens* (Bertol.) Pax in Pflanzenr. IV, 147, XI: 122 1919
65. *R. communis* f. *radiatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 64 1956
66. *R. communis* f. *rufescens* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 55 1956
67. *R. communis* f. *russatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 57 1956
68. *R. communis* f. *rutilans* Müll.Arg in Prodr. 15(2): 1017 1866
69. *R. communis* f. *scaber* (Bertol. ex Moris) Müll.Arg in Prodr. 15(2): 1019 1866
70. *R. communis* f. *scriptus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 59 1956
71. *R. communis* f. *sordidus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 33 1956
72. *R. communis* f. *stigmatosus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 28 1956
73. *R. communis* f. *striatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 63 1956
74. *R. communis* f. *subpurpurascens* Müll. Arg in Prodr. 15(2): 1020 1866
75. *R. communis* f. *subrotundus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 54 1956
76. *R. communis* f. *subviridis* Müll.Arg in Prodr. 15(2): 1019 1866
77. *R. communis* f. *sulcatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 38 1956
78. *R. communis* f. *tigrinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 39 1956
79. *R. communis* f. *umbrinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 59 1956
80. *R. communis* f. *venosus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 37 1956
81. *R. communis* f. *vinatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 52 1956
82. *R. communis* f. *viridis* (Willd.) Müll.Arg in Prodr. 15(2): 1020 (1866)
83. *R. communis* f. *zebrinus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 60 1956
84. *R. communis* f. *zollingeri* Müll.Arg in Prodr. 15(2): 1018 1866

85. *R. communis* f. *zonatus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 50 1956
86. *R. communis* subsp. *africanus* (Mill.) Nyman in Consp. Fl. Eur. 647. 1881 (1881)
87. *R. communis* subsp. *indicus* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 35 (1980)
88. *R. communis* subsp. *manshuricus* V.Bork in Descr. Var. Azcherkaya 106. 1936 (1936)
89. *R. communis* subsp. *mexicanus* Popova in Bukasov S.M. Vozdelyv. Rast. Meksiki 409. 1931 (1931)
90. *R. communis* subsp. *persicus* Popova in Kleshchevina izd. VIR 27. 1930 (1930)
91. *R. communis* subsp. *ruderalis* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 38 (1980)
92. *R. communis* subsp. *sanguineus* Popova in Kleshchevina izd. VIR 35. 1930 (1930)
93. *R. communis* subsp. *scaber* (Bertol. ex Moris) Nyman in Consp. Fl. Eur. 647. 1881 (1881)
94. *R. communis* subsp. *sinensis* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 34 (1980)
95. *R. communis* subsp. *zanzibarinus* Popova in Kleshchevina izd. VIR 43. 1930 (1930)
96. *R. communis* var. *aegyptiacus* (G.Popova) Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 40 (1980)
97. *R. communis* var. *africanus* Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1019. 1866
98. *R. communis* var. *amblyocalyx* Müll.Arg in Prodr. 15(2): 1019 1866
99. *R. communis* var. *americanus* Müll.Arg in Prodr. 15(2): 1017 (1866)
100. *R. communis* var. *armatus* (Andrews) Steud in Nomencl. Bot., ed. 2, 2: 459 (1841)
101. *R. communis* var. *badius* (Rchb.) Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1019. 1866
102. *R. communis* var. *bailundensis* J.M.Coult in Bull. Soc. Portug. Sci. Nat. 1918: 82
103. *R. communis* var. *benguelensis* Müll.Arg in J. Bot. 1: 337. 1864
104. *R. communis* var. *brasiliensis* Müll.Arg in Fl. Bras. 11(2): 421 (1874)
105. *R. communis* var. *brevinodis* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 32 (1980)
106. *R. communis* var. *caesius* Popova in Kul't. Fl. SSSR 7: 287. 1941
107. *R. communis* var. *communis*
108. *R. communis* var. *glaucus* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 37 (1980)
109. *R. communis* var. *griseofolius* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 36 (1980)
110. *R. communis* var. *hybridus* (Besser) Müll. Arg in Prodr. 15(2): 1020 (1866)
111. *R. communis* var. *indehiscens* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 33 (1980)
112. *R. communis* var. *inermis* (Mill.) Pax & K.Hoffm in Pflanzenr. IV, 147, XI: 122.

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113. *R. communis* var. *japonicus* E.D.Popova & Moshkin in Nauch. Trudy Vasknil 35 1980
114. *R. communis* var. *japonicus* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 35 (1980)
115. *R. communis* var. *krappa* Steud in Nomencl. Bot., ed. 2, 2: 459 (1841) nom. inval.
116. *R. communis* var. *leucocarpus* (Bertol.) Müll.Arg in Prodr. 15(2): 1018 (1866)
117. *R. communis* var. *lividus* (Jacq.) Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1018. 1866
118. *R. communis* var. *macrocarpus* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 27 1956
119. *R. communis* var. *macrophyllus* Müll.Arg in Prodr. 15(2): 1020 (1866)
120. *R. communis* var. *megalospermus* (Delile) Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1017. 1866
121. *R. communis* var. *mexicanus* (G.Popova) Moshkin in Kleshchevina (Nauch. Trudy Vasknil) : 40 (1980)
122. *R. communis* var. *microcarpus* Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1020. 1866
123. *R. communis* var. *microspermus* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 31 (1980)
124. *R. communis* var. *minor* (Mill.) Steud in Nomencl. Bot., ed. 2, 2: 459 (1841)
125. *R. communis* var. *nanus* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 38 (1980)
126. *R. communis* var. *purpurascens* (Bertol.) Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1018. 1866
127. *R. communis* var. *reichenbachianus* Müll. Arg in Prodr. [A. P. de Candolle] 15(2): 1019. 1866
128. *R. communis* var. *rheedianus* Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1020. 1866
129. *R. communis* var. *roseus* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 31 (1980)
130. *R. communis* var. *rugosus* Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1018. 1866
131. *R. communis* var. *sanguineus* Baill in Recueil Observ. Bot. 1: 342. 1861
132. *R. communis* var. *speciosus* (Burm.f.) Müll.Arg in Prodr. [A. P. de Candolle] 15(2): 1021. 1866
133. *R. communis* var. *spontaneus* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 39 (1980)
134. *R. communis* var. *subpurpurascens* Müll. Arg in Prodr. 15(2): 1020 (1866)
135. *R. communis* var. *undulatus* (Besser) Steud in Nomencl. Bot., ed. 2, 2: 459 (1841)
136. *R. communis* var. *vasconcellosii* T.Carvalho in Anais Junta Invest. Ultramar 11(4): 33. 1956
137. *R. communis* var. *violaceocaulis* Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 34 (1980)

138. *R. communis* var. *virens* Popova in Kul't. FL. SSSR 7: 290. 1941
139. *R. communis* var. *viridis* G.Popova & Moshkin in Kleshchevina (Nauch. Trudy Vasknil): 32 (1980)
140. *R. compactus* C.Huber in Cat. Print. 1865: 8 (1865)
141. *R. digitatus* Noronha in Verh. Batav. Genootsch. Kunsten 5(4): 26 (1790)
142. *R. europaeus* T.Nees in Gen. Fl. Germ. : 38 (1833)
143. *R. gibsonii* auct in Gard. Chron. II, 4: 692 1877
144. *R. giganteus* hort. ex Pax & K.Hoffm in Pflanzenr., IV, 147, IX: 126 (1919)
145. *R. glaucus* Hoffmanns in Verz. Pfl. Nachtr. 2: 199 (1826)
146. *R. hybridus* Besser in Cat. Jard. Bot. Krzemieniec, Suppl. 2: 13 (1814)
147. *R. inermis* Mill in Gard. Dict. ed. 8: n.º 6 (1768)
148. *R. japonicus* Thunb in Ricin.: 4 (1815)
149. *R. krappa* Hort.Berol. ex Steud in Nomencl. Bot., ed. 2, 2: 459 (1841)
150. *R. laevis* DC in Rapp. [Not.] Pl. Rar. Genève 1: 31 (1823)
151. *R. leucocarpus* Bertol in Giorn. Arcadico Sci. 21: 192 (1824)
152. *R. lividus* Jacq in Misc. Austriac. 2: 360 (1781)
153. *R. macrocarpus* Popova in Kul't. FL. SSSR 7: 278. 1941 (1941)
154. *R. macrocarpus* var. *nudus* Popova in Kul't. FL. SSSR 7: 287. 1941
155. *R. macrophyllus* Bertol in Giorn. Arcadico Sci. 21: 192 (1824)
156. *R. medicus* Forssk in Fl. Aegypt.-Arab. : 164 (1775)
157. *R. medius* J.F.Gmel in Syst. Nat. ed. 13[bis] : 1615 (1792)
158. *R. megalosperma* Delile in Voy. Méroé 4: 89 (1827)
159. *R. megalospermus* Delile in Voy. Méroé 4: 89 (1827)
160. *R. messeniacus* Heldr in Exsicc. (Herb. Graec. Norm.) 1899: n.º 1480. (1899)
161. *R. metallicus* hort. ex Pax & K.Hoffm in Pflanzenr. , IV, 147, IX: 126 (1919)
162. *R. microcarpus* Popova in Kul't. FL. SSSR 7: 287 (1941)
163. *R. microcarpus* var. *atrovirens* Popova in Kul't. FL. SSSR 7: 290. 1941
164. *R. microcarpus* var. *spontaneus* Popova in Kul't. FL. SSSR 7: 288. 1941
165. *R. minor* Mill in Gard. Dict. ed. 8: n.º 7 (1768)
166. *R. nanus* Balb in Cat. Stirp. (1813): 65 (1813)
167. *R. obermannii* Groenland in Rev. Hort. (Paris), sér. 4, 7: 601 (1858)
168. *R. peltatus* Noronha in Verh. Batav. Genootsch. Kunsten 5(4): 2 (1790)
169. *R. perennis* hort. ex Steud in Nomencl. Bot., ed. 2, 2: 459 (1841)
170. *R. persicus* Popova in Trudy Byuro Evgen. 16: 229 (1926)
171. *R. purpurascens* Bertol in Misc. Bot. 9: 4 (1851)

172. *R. ruber* Miq in FL. Ned. Ind. 1(2): 390 (1859)
173. *R. rugosus* Mill in Gard. Dict. ed. 8: n.º 4 (1768)
174. *R. rutilans* Müll.Arg in Prodr. 15(2): 1017 (1866)
175. *R. sanguineus* hort. ex Groenland in Rev. Hort. (Paris), sér. 4, 7: 601 (1858)
176. *R. scaber* Bertol. ex Moris in Stirp. Sard. Elench. 1: 41 (1827)
177. *R. speciosus* Burm.f in FL. Indica: 207 (1768)
178. *R. spectabilis* Blume in Bijdr. FL. Ned. Ind.: 623 (1826)
179. *R. tunisensis* Desf in Tabl. École Bot., ed. 3: 340 (1829)
180. *R. undulatus* Besser in Cat. Jard. Bot. Krzemieniec: 90 (1811)
181. *R. urens* Mill in Gard. Dict. ed. 8: n.º 3 (1768)
182. *R. viridis* Willd in Sp. Pl., ed. 4, 4: 564 (1805)
183. *R. vulgaris* Garsault in Fig. Pl. Méd.: 66 (1764)
184. *R. vulgaris* Mill in Gard. Dict. ed. 8: n.º 1 (1768)
185. *R. zanzibarensis* auct in Ill. Hort. 41: 99 1894
186. *R. zanzibarinus* Popova in Kul't. Fl. SSSR 7: 292 (1941)

Ecogeographical Grouping

The *R. communis* is divided into six subspecies based on ecogeographical grouping (Kulkarni

and Ramanamurthy, 1977; Moshkin and Dvoryadkina, 1986; Weiss, 2000) as

1. *R. communis* subsp. *persicus*
2. *R. communis* subsp. *chinensis*
3. *R. communis* subsp. *zanzibarinus*
4. *R. communis* subsp. *sanguineus*
5. *R. communis* subsp. *africans*
6. *R. communis* subsp. *mexicans*

Botanical Description

Monoecious, erect shrub or small tree, often single-stemmed or much-branched, ca. 8 m tall; younger parts glaucous, whole plant often reddish or purplish. Stipules sheath ovate or connate, 2-3 cm long, leaving a circular scar when fallen. Leaves alternate, peltate, petiole 5-30 cm long, petiolar glands variously shaped; leaf blade palmately 7-11 lobed, median lobe usually 10-20 × 2-5 cm, lateral lobes progressively smaller; lobes lanceolate, acutely acuminate, margin serrate. Inflorescence ca. 10-30 cm long. Bracts ca. 1 cm long; bracteoles smaller. Flower in terminal panicle racemes, unisexual; male flowers: pedicels ca. 1 cm long; calyx lobes elliptic-ovate, acute, yellowish green; stamens 7-8 mm long, pale yellow; female flowers: pedicels 3-8 mm long, extending to 2 cm or more in fruit; sepals ca. 5 mm, lanceolate, acuminate, purplish, ovary trilobate-subglobose. Fruit trilobate, ellipsoid or ovoid, echinate, sometimes smooth. Seed 7-12 mm, grayish, silvery, or beige with darker markings; caruncle depressed-conical (Fig. 2A, B).



Fig. 2A Plant habit



Fig. 2B (a) Plant, (b) Pistillate flower, (c) L.S of pistillate flower, (d) T.S of pistillate flower, (e) staminate flower, (f) Polyadelphous stamens, (g) Stamen, (h) Fruit, (i) Split seed, (j) Seed

Chromosome Number

The basic chromosome numbers are 10 ($x=10$). According to Richharia (1937), castor is regarded as a secondary balanced autopolyploid with $N = 10$. The haploid constitution was hypothesized to be AAA, BB, CC, DD, and E based on the greatest number of secondary associations (5) seen during metaphases I and II (Lavanya et al., 2018). Chan et al. (2010) published an initial draft of their study, which examined the cultivated variety "Hale", with a 4.6× coverage. An estimated 350 Mb, or 31,000 genes, make up the castor genome (Chan et al., 2010). Lu et al. (2022) published the second genome sequencing of an Ethiopian wild castor. With 4303 castor accessions from 39 different countries, the National Bureau of Plant Genetic Resources in India is the largest germplasm repository (Landoni et al., 2023).

Anatomical Features

Structure of the Leaf

The leaf is characterized by single layer of epidermis which is covered by a thin layer of cuticle. There are multicellular trichomes in the epidermis. In the lower epidermis, a few stomata are visible. Ten to twelve layers of collenchyma lie beneath the upper epidermis and four to five layers lie above the lower epidermis in the midrib. There is a significant area of parenchymatous cells with four vascular bundles in the middle between the two collenchymas. Micro-, prismatic, and rosette crystals are observed in the parenchymatous zone. There are a few oil glands in the lower collenchymatous tissues. Mesophyll in the wings gave rise to three to four spongy layers of parenchyma and a single layer of palisade (Fig. 3).

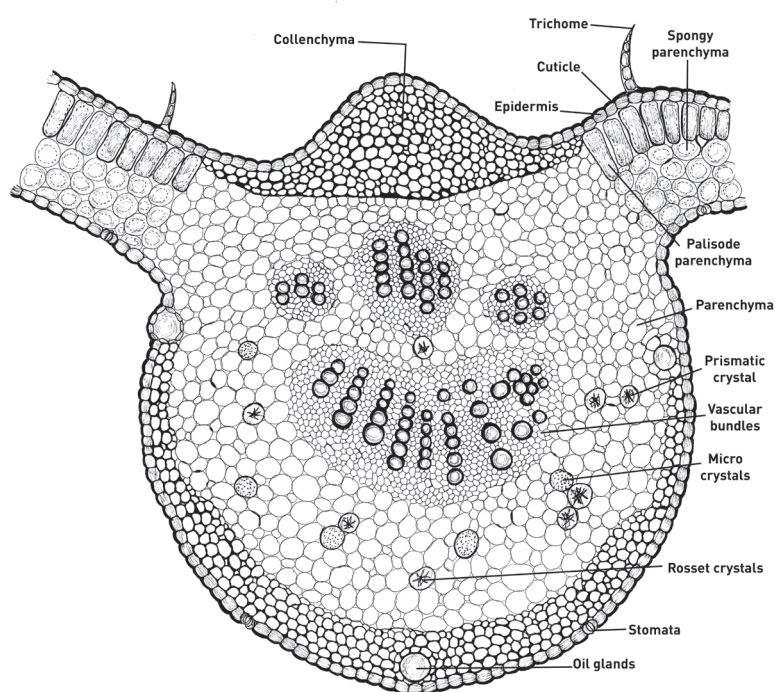


Fig. 3 T.S. of leaf

Structure of the Stem

Transverse section of stem showed outer epidermal layer which is covered by a thin layer of cuticle and follows the several layer of collenchymatous cells. Inside the collenchyma,

several layers of parenchymatous cells are present that having eight vascular bundles which are arranged in a ring. A large pith is present in the centre (Fig 4).

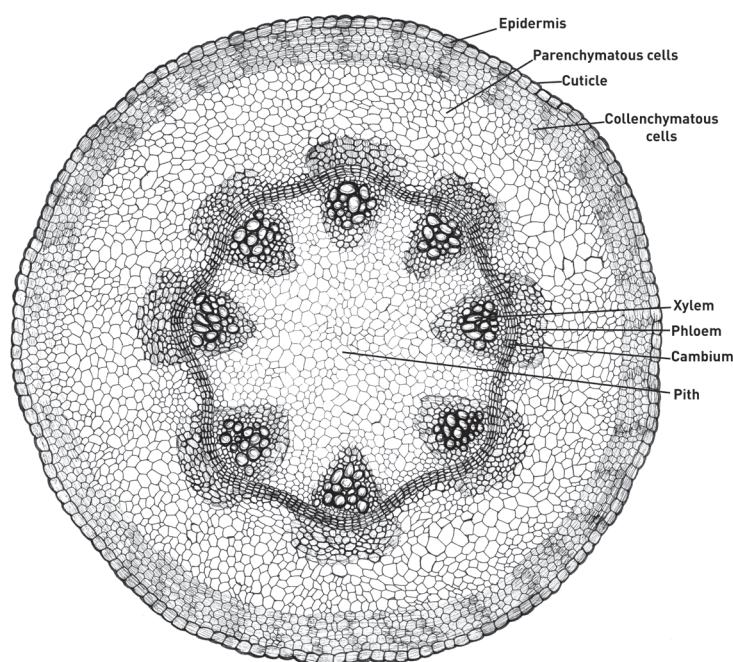


Fig. 4 T.S. of stem

Structure of the Root

The root shows a similar pattern as the dicot root. The outermost layer periblem or bark is present with the cell's debris. The epidermis follows the several layers of collenchymatous

cells. These cells have vascular bundles. Phloem occurs on outer side of the vascular bundle whereas xylem occupies the center of the vascular bundle (Fig. 5).

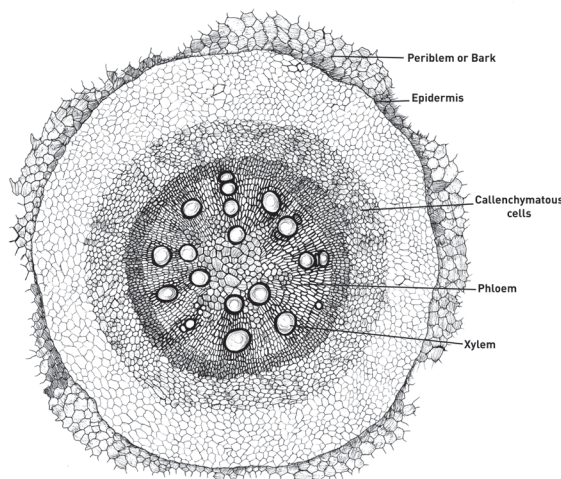


Fig. 5 T.S. of root

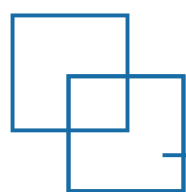
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CHAPTER
02

Bibliometric Analysis



INTRODUCTION

Ricinus communis L., commonly known as the castor oil plant, is a soft-wooded shrub species of the Euphorbiaceae family, widespread throughout tropical regions (Elkousy et al., 2021). Extensive phytochemical analysis has identified alkaloids, flavonoids, tannins, sterols, and terpenes (Gupta et al., 2024). The major phytoconstituents in this plant are kaempferol, quercetin, rutin, gallic acid, epicatechin and ellagic acid. *R. communis* has been used in traditional medicine for over 4,000 years, with every part of the plant employed to prevent diseases without adverse effects when used in proper dosages. Moreover, when cattle consume the leaves of this plant, there has been an increase in production of milk (Elkousy et al., 2021). The oil extracted from its leaves has antifungal and antimicrobial properties and is also used to alleviate flatulence in infants. Castor oil, extracted from its seeds is highly miscible with alcohol, has a lower melting point and better oxidation stability. These characteristics make it versatile for a range of uses, such as a purgative, laxative, lubricant, and an ingredient in cosmetics (Subramaniyan, 2020). Additionally, it plays a role in the production of soaps, inks, plastics, waxes, and textile dyes. Moreover, numerous extracts from *R. communis* exhibit significant pharmacological properties. These include antifungal, antimicrobial, hepatoprotective, antidiabetic, antifertility, antinociceptive, antioxidant, larvicidal, insecticidal, anti-inflammatory, free radical scavenging, wound healing, bone regenerative, and antiviral activities ((Elkousy et al., 2021). The multifaceted therapeutic potential of *R. communis* paves the way for further exploration and development of its pharmacological applications.

Bibliometric analysis is a fundamental technique in modern scientific analysis, providing a comprehensive evaluation of the scholarly area encompassing a particular subject or topic (Verano-Tacoronte et al., 2024). The present study examines the research landscape of *R. communis* through bibliometric analysis, exploring the extensive literature, research trends, and knowledge dissemination associated with this versatile and widely studied plant species. The bibliometric analysis enables the investigation of both quantitative and qualitative extents within



scholarly publications, providing researchers with the means to scrutinize patterns, trends, and the evolutionary trajectory of scientific literature related to *R. communis* (Jing et al., 2023). This analytical approach involves examining publication metrics, citation patterns, author collaborations, geographical distributions, and thematic emphases within the body of scientific literature (Vieira, 2022). Scientifically analyzing bibliographic data of *R. communis* provides researchers with a comprehensive understanding of the extent and scope of research conducted on this plant species.

The objective of this bibliometric analysis was to explore the research landscape surrounding *R. communis* comprehensively. By exploring scholarly literature, the study aims to exhibit past research trends, recognize key contributors, discern citation patterns, and outline collaborative networks within the field. The primary goal was to provide a nuanced understanding of the existing knowledge framework concerning *R. communis*, thereby enabling the identification of research gaps and guiding future investigative endeavors. Furthermore, strategic decision-making in various domains including agricultural practices, environmental conservation, and pharmaceutical applications will be emphasized.

Insights with Data Source and Tools

The study investigates the research landscape of *Ricinus communis* L. through a detailed bibliometric analysis, aiming to provide a comprehensive understanding of the scope, impact, and evolving trends in academic publications related to this plant species. The scholarly articles used for this in-depth analysis were sourced from Dimensions.ai, with the specific search parameter being the exact phrase "*Ricinus communis*" covering publications from the year 2000 to 2023. To organize and perform initial assessments of the data, Microsoft Excel was utilized. For a more detailed bibliometric analysis, tools

such as lens.org and VosViewer (Version 1.6.19) were employed. These tools facilitated the examination of citation networks, co-authorship patterns, and the generation of visual representations of bibliographic data, as supported by several studies (Cavalcante et al. 2021; Sarjidan et al., 2023). The study's thematic areas were identified using the integrated features of lens.org, enabling an exhaustive exploration of key research domains related to *R. communis*. This approach allows the researchers to map out significant trends and patterns within academic literature, providing valuable insights into the development and impact of research on this botanical species.

Comprehensive Data-driven Insights

A bibliometric analysis of scholarly publications on *R. communis* between 2000 and 2023 offers a thorough insight into their worldwide reach, collaborative networks, and impact. During this period, a total of 3862 scholarly articles were published on this subject by 2975 organizations across 109 nations, involving contributions from 14459 authors. Particularly, 228 authors demonstrated specialized expertise through independent publications, highlighting their significant contributions to the field. These scholarly works were published in 1785 esteemed journals, indicating a broad and diverse dissemination platform for *R. communis* research. The average citation rate of 16.78 citations per document underscored the substantial impact these publications had within the scholarly community, reflecting the relevance and influence of the research. Over time, research on *R. communis* progressed from foundational taxonomy and ecology studies to applied research in agronomy, pharmacology, ecology, and molecular biology, indicating a growing interest in practical applications. Global contributions and collaborative networks among authors and organizations from various countries underscored widespread interest and potential for international collaboration, vital for advancing knowledge and innovation in agriculture, medicine, pharmacology, and environmental science. Ultimately, the bibliometric analysis provides a comprehensive understanding of the research

landscape surrounding *Ricinus communis*. It emphasizes the multifaceted nature and significant scientific interest in this species, pointing towards numerous opportunities for future research and innovative applications across diverse fields.

Temporal Evolution and Growth Analysis

A total of 3862 documents were discovered after extensive searches across bibliographic databases via Dimensions.ai. These demonstrated a variety of study forms, including 3621 articles, 159 chapters, 42 preprints, 36 proceedings, and 4 edited books. Spanning from 2000 to 2023, the dataset showed increasing trends in scholarly output over two decades. The research landscape began modestly with 53 publications in 2000, gradually increasing to 96 by 2001, indicating a growing interest in exploring the properties and applications of *R. communis* L. A significant surge in research output was observed from 2010 to 2015, with the number of publications 156 in 2010 and 207 in 2015. This period signified the emergence of the plant as a prominent subject of study within the scientific community. Despite variations, the overall trend remained relatively steady, indicating sustained interest and continued research activity. The growth analysis revealed patterns of exponential growth ($R^2=0.9049$), particularly during the early and mid-2010s, followed by a plateauing in the latter years of the dataset.

In the year 2021, the highest volume of scholarly articles (286) was published during 2000 to 2023 (Fig. 1). While growth may have stabilized, the sustained level of research output indicated a mature and established research field with continued relevance and interest among researchers. Throughout the

timeline, periodic fluctuations in research output suggested cyclical patterns influenced by factors such as funding, scientific trends, and research priorities. Understanding these trends is crucial for contextualizing research efforts, identifying emerging areas of inquiry, and informing future directions in the study of *R. communis* L.

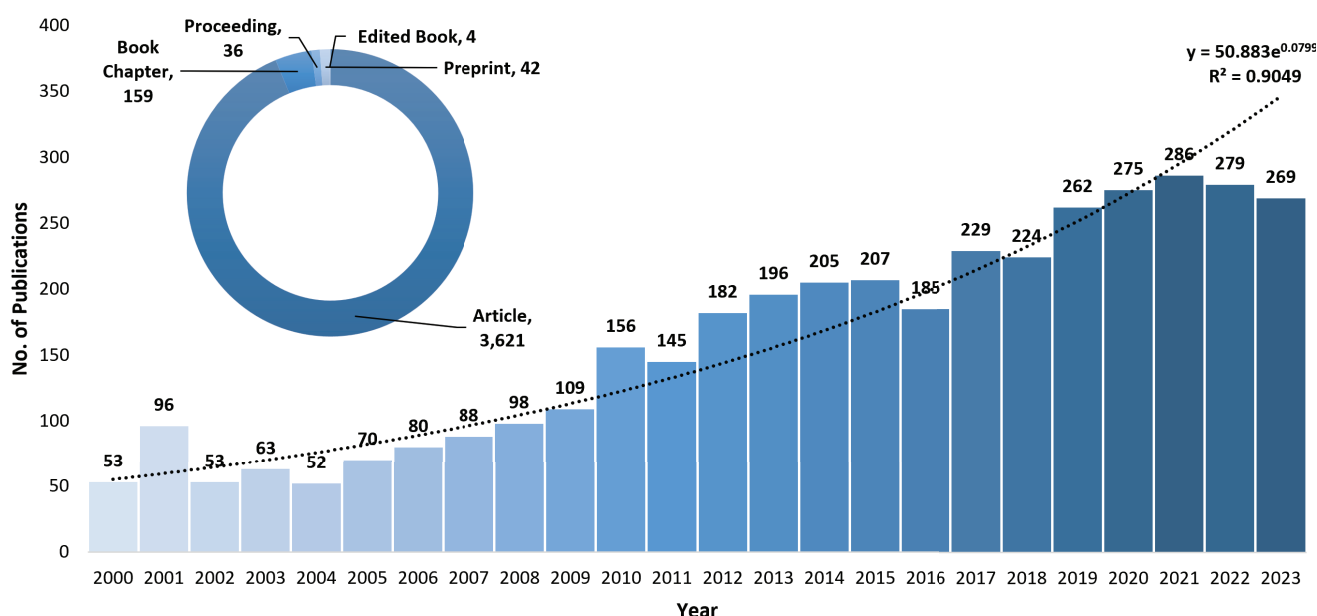


Fig. 1 Publication trends and distribution types in *R. communis* research

Citation Analysis

Citation analysis is a fundamental tool in bibliometric research, offering insights into the impact and dissemination of scholarly work within a specific field or topic. Applying this method to the research landscape of *R. communis*, the data revealed exciting trends over the past two decades. From the year 2000 to 2010, there is a noticeable upward trajectory in the number of citations, peaking in 2010 with 4667 citations (Fig. 2). This peak might indicate a period of significant interest or breakthroughs in *R. communis*

research during that time. However, from 2013 onwards, there appears to be a gradual decline in citation counts, with fluctuations but a general downward trend persisting until 2023. Such fluctuations could be influenced by several factors such as changes in research focus, emergence of new topics, or shifts in scholarly communication practices. Unusually, the sharp decrease in citations from 2022 to 2023 suggests a potential decline in ongoing interest or relevance in *R. communis* research, demanding further investigation into the underlying reasons behind this trend.

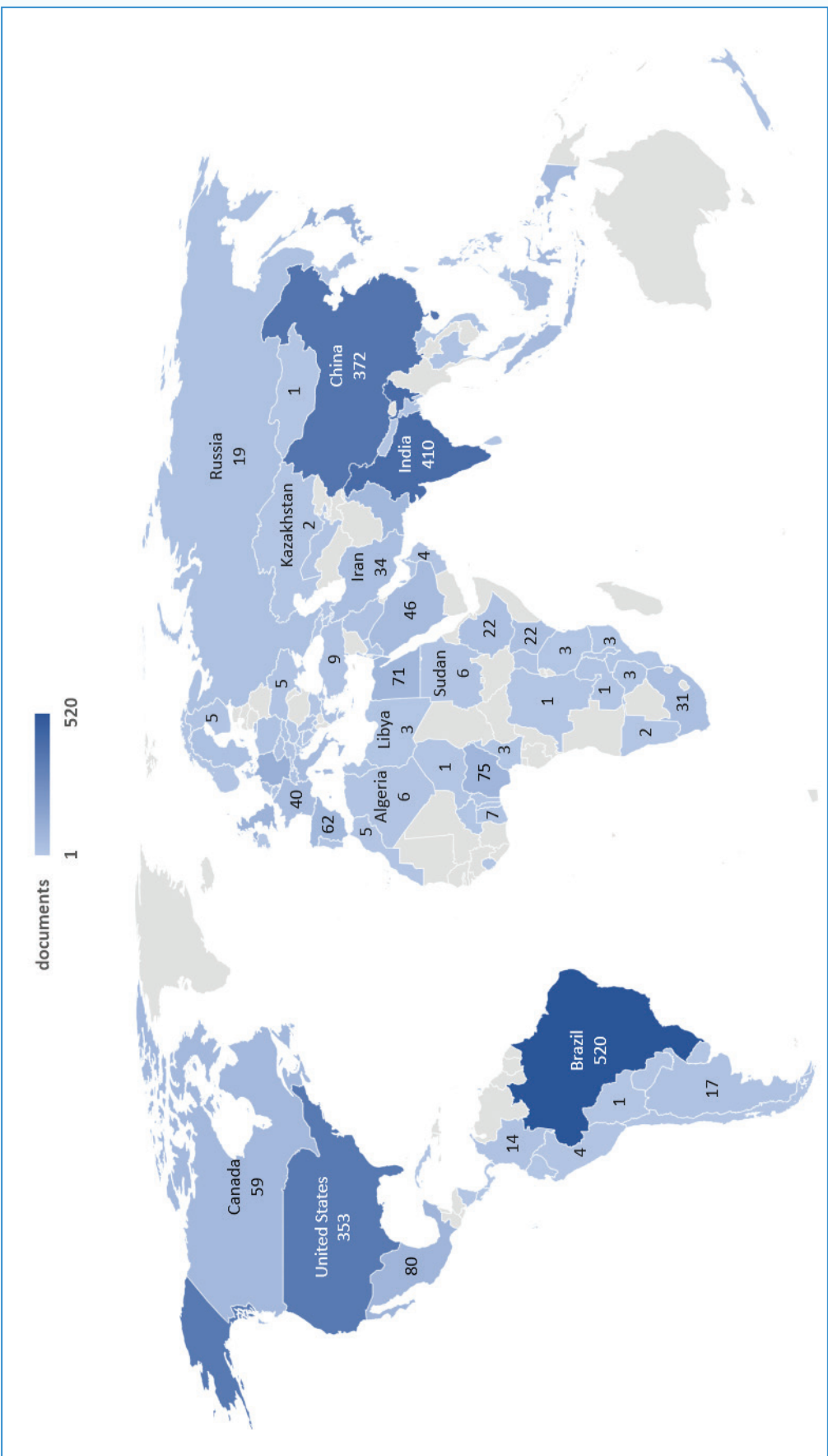


Fig. 3 Global distribution of research on *R. communis*

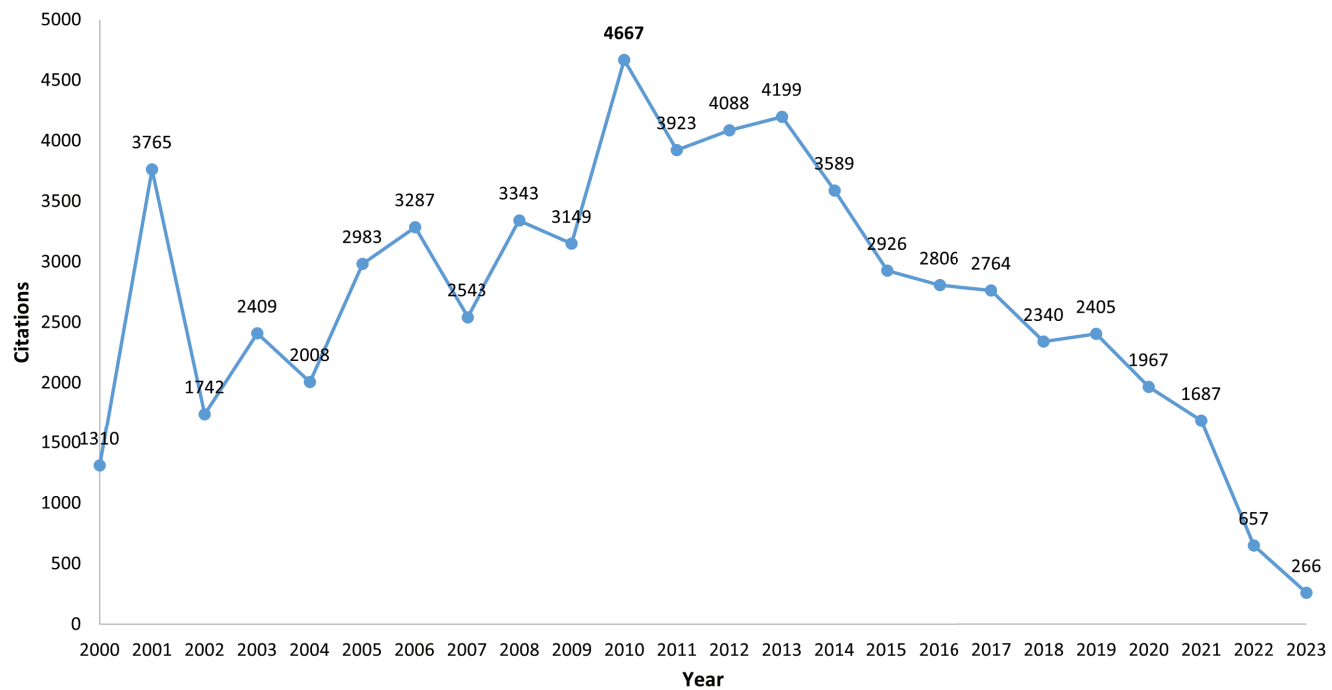


Fig. 2 Citation trends for *R. communis* research over time

Country-wise Publication Analysis

In the examination of publication output based on countries, insights were collected into the geographical distribution of research activity concerning *R. communis*. Among the countries contributing significantly, Brazil emerges as a dominant contributor with 520 documents and 7,521 citations, indicating a vigorous research community and substantial academic impact. Following closely is India, with 410 documents and 9,653 citations, highlighting its substantial contribution to the literature on *R. communis*. The United States, with 353 documents and 12,843 citations, underscores its pivotal role in the research

landscape. Other prominent contributors include China, with 372 documents and 7,624 citations, and Japan, with 110 documents and 2,392 citations. This analysis underscores the global significance of *R. communis* research, with contributions spanning across continents and reflecting diverse scientific perspectives and methodologies (Fig. 3). Interestingly, despite differences in research output, countries like Germany, United Kingdom, Mexico, and Nigeria highlighted considerable contribution in the research output on *R. communis*. This analysis underscores the global significance of *R. communis* research, with contributions spanning across continents and reflecting diverse scientific perspectives and methodologies.

Most Prominent Authors

Among all authors, Aizhong Liu emerged as a leading figure with 34 documents and 852 citations, reflecting a strong influence within the field. Following closely, Wei Xu with 21 documents and 620 citations also demonstrated significant impact. John Browse has made prominent contributions with 16 documents and a substantial citation count of 1,066, indicating considerable recognition in the research community. Moreover, Liv S.

Severino, Grace Q. Chen, Fenglan Huang, and Lavanya C emerged as leading figures, each with 14 documents and citations of 558, 394, 74 and 4, respectively (Fig. 4). They are closely followed by Thomas A. Mckeen, and Zhi Zou, each with 13 documents have garnered 454 and 246 citations, respectively, indicating a strong influence in the field. These authors collectively shape the research landscape through their prolific output and impactful work, paving the way for further advancements in the field.

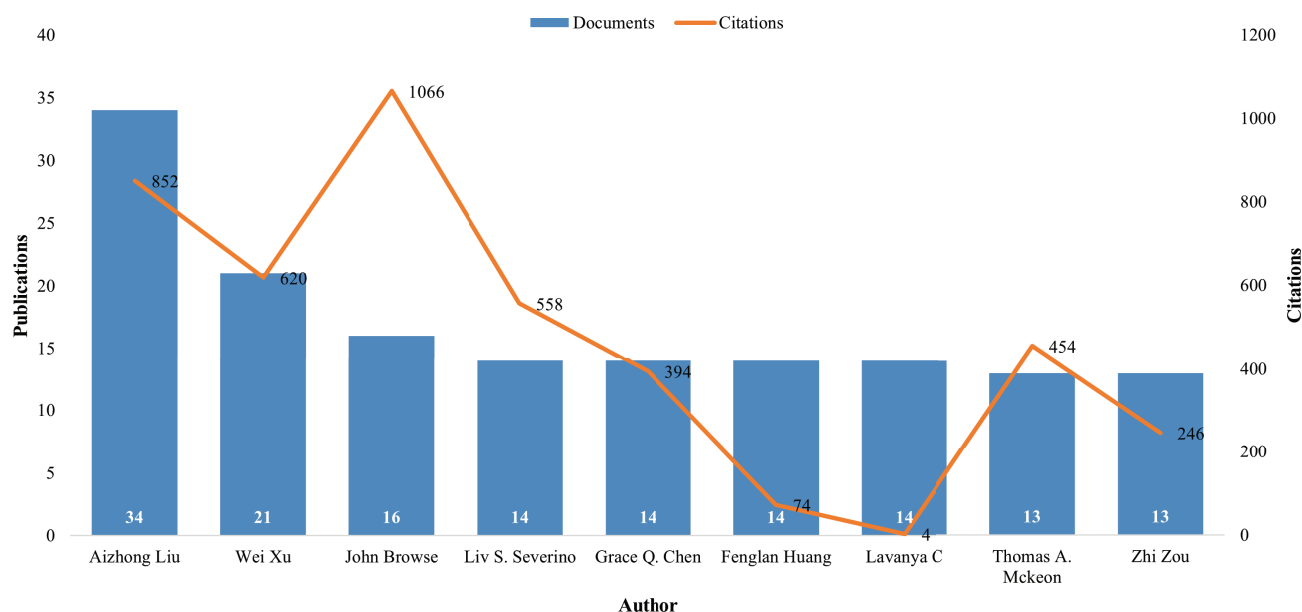


Fig. 4 Most prominent authors based on research contributions to *R. communis*

Highly Cited Articles

The top 10 highly cited research articles on *R. communis* provide a comprehensive overview of its diverse applications and properties. The most highly cited article published in 2001 was "Group Epitope Mapping by Saturation Transfer Difference NMR To Identify Segments of a Ligand in Direct Contact with a Protein

Receptor" with 1078 citations (Mayer and Meyer, 2001). Additionally, "Bone marrow contributes to renal parenchymal turnover and regeneration" (2001) gained 570 citations, indicating its substantial contribution to understanding the role of bone marrow in regeneration (Poulsom et al., 2001). "Ricin Poisoning: A Comprehensive Review" (2005) received 565 citations, demonstrated its relevance in the

context of ecological management (Audi et al., 2005). "Synthesis of Neoglycopolymers by a Combination of "Click Chemistry" and Living Radical Polymerization" (2006) is prominent with 545 citations, reflecting its impact on polymer chemistry (Ladmiral et al., 2006). Moreover, "Draft genome sequence of the oilseed species *Ricinus communis*" (2010) stored 430 citations, emphasizing its significance in genome sequence of oil seed species (Chan et al., 2010). "Influence of metal resistant-plant growth-promoting bacteria on the growth of *Ricinus communis*

in soil contaminated with heavy metals " and "Pyrolysis kinetics and thermodynamic parameters of castor (*Ricinus communis*) residue using thermogravimetric analysis" both received 314 citations in 2008 and 2017, respectively (Rajkumar and Freitas, 2008; Kaur et al., 2017). Other articles have citations less than 300 indicating their importance in different research areas (Table 1). These highly cited articles collectively represent significant contributions to the literature on *R. communis* L., guiding further research and informing practice within the field.

Table 1 Top 10 highly cited research articles published on *R. communis*

Rank	Title	Source	Year	Citations	Reference
1	Group Epitope Mapping by Saturation Transfer Difference NMR To Identify Segments of a Ligand in Direct Contact with a Protein Receptor	Journal of the American Chemical Society	2001	1078	Mayer and Meyer, 2001
2	Bone marrow contributes to renal parenchymal turnover and regeneration	The Journal of Pathology	2001	570	Poulsom et al., 2001
3	Ricin Poisoning: A Comprehensive Review	JAMA	2005	565	Audi et al., 2005
4	Synthesis of Neoglycopolymers by a Combination of Click Chemistry and Living Radical Polymerization	Journal of the American Chemical Society	2006	545	Ladmiral et al., 2006
5	Draft genome sequence of the oilseed species <i>Ricinus communis</i>	Nature Biotechnology	2010	430	Chan et al., 2010
6	Influence of metal resistant-plant growth-promoting bacteria on the growth of <i>Ricinus communis</i> in soil contaminated with heavy metals	Chemosphere	2008	314	Rajkumar and Freitas, 2008

Rank	Title	Source	Year	Citations	Reference
7	Pyrolysis kinetics and thermodynamic parameters of castor (<i>Ricinus communis</i>) residue using thermogravimetric analysis	Biore-source Technology	2017	314	Kaur et al., 2017
8	Cytokines, chemokines, and cytokine receptors in human microglia	Journal of Neuroscience Research	2002	299	Lee et al., 2002
9	Metabolic engineering of hydroxy fatty acid production in plants: RcDGAT2 drives dramatic increases in ricinoleate levels in seed oil	Plant Biotechnology Journal	2008	281	Burgal et al., 2008
10	Long-term soil management effects on crop yields and soil quality in a dryland Alfisol	Soil and Tillage Research	2005	270	Sharma et al., 2005

Most Active Journals

The present study showed the top journals of *R. communis* research based on their impact factor, publications, and citations. Industrial Crops and Products, published by Elsevier, appeared as the most active journal with an impressive impact factor of 6.44, featuring 114 documents and garnering 3210 citations. Following closely, Plant Physiology by Oxford University Press stands out with its high impact factor of 7.14 and substantial citation count of 1704 with 29 documents. Indian Journal of Agronomy by Indian Council of Agricultural Research (ICAR) having impact factor 0.304 and substantial citation count of 14 with 28 documents stands next. Other prominent

journals include Toxins by MDPI, Planta by Springer, and International Journal of Current Microbiology and Applied Sciences by Excellent Publishers, had an impact factor of 5.07, 3.19, and 1.95 each contributing 25 documents with 936, 846 and 29 citations, respectively. These journals collectively provide a comprehensive view of the advancements, challenges, and innovations in the study of this versatile plant species. Moreover, the journals PLOS One, Environmental Science and Pollution Research, Scientific Reports each contribute significantly to the research landscape of *R. communis* (Table 2). Overall, the study's results assisted readers and researchers in selecting relevant and valuable materials for their *R. communis* research.

Table 2 Top journals in *R. communis* research have the highest published document and citations

Rank	Source	Publisher	Impact factor	Documents	Citations	Citations per Document
1	Industrial Crops and Products	Elsevier	6.45	114	3210	28.16
2	Journal of Oilseeds Research	Indian Society of Oilseeds Research	0.12	77	22	0.29
3	Plant Physiology	Oxford University Press	7.14	29	1704	58.76
4	Indian Journal of Agronomy	Indian Council of Agricultural Research (ICAR)	0.30	28	14	0.50
5	Toxins	MDPI	5.07	25	936	37.44
6	Planta	Springer	3.19	25	846	33.84
7	International Journal of Current Microbiology and Applied Sciences	Excellent Publishers	1.95	25	29	1.16
8	PLOS One	Public Library of Science (PLOS)	3.75	23	742	32.26
9	Environmental Science and Pollution Research	Springer	5.19	22	701	31.86
10	Scientific Reports	Nature Publishing Group	5.00	21	306	14.57

Top Productive Organizations

The examination of scientific contributions made to the *R. communis* ecology demonstrated diverse trends in recognition and effect among various successful groups. The study lists the top organizations according to how much research they have done on *R. communis*. Among all organizations, Universidade de São Paulo was the leading one with 86 documents and 1499 citations, followed closely by São Paulo State University with 75 documents and 1202 citations. Brazilian Agricultural Research Corporation secures the third position with 68

documents and 1235 citations. Other prominent contributors include Federal University of Campina Grande, Indian Institute of Oilseeds Research, and University of Chinese Academy of Sciences (Table 3). These institutions demonstrated significant scholarly output and impact in the field, indicating their pivotal role in advancing knowledge and understanding of *R. communis*. Other contributors include the Indian Institute of Oilseeds Research and the University of Chinese Academy of Sciences, reflecting a diverse international collaboration in the study of this important plant species.

Table 3 Top organizations' contributions to *R. communis* research

Rank	Organization	Country	Documents	Citations	Citations per Document
1.	Universidade De São Paulo	Brazil	86	1499	17.43
2.	São Paulo State University	Brazil	75	1202	16.03
3.	Brazilian Agricultural Research Corporation	Brazil	68	1235	18.16
4.	Federal University of Campina Grande	Brazil	44	491	11.16
5.	Indian Institute of Oilseeds Research	India	41	805	19.63
6.	University of Chinese Academy of Sciences	China	38	1132	29.79
7.	Western Regional Research Center	United States	36	1406	39.06
8.	Kunming Institute of Botany	China	35	924	26.40
9.	Federal Rural University of Pernambuco	Brazil	35	526	15.03
10.	Universidade Federal Do Ceará	Brazil	30	738	24.60

Top Fields of Study

The present study analyzed the occurrence of terms in significant academic domains using a dataset consisting of 4712 scholarly documents sourced from lens.org. The research results were based on document frequency, brought attention to a wide range of subjects. The dominant fields included Biology, with 2886 documents, *Ricinus*-specific studies, accounting for 2564 documents, and Botany, comprising 1337 documents. These high counts highlighted a collective interest in understanding not only the broader biological context of the plant but also its specific attributes, such as morphology and taxonomical classification. Moreover, Chemistry and Biochemistry were prominent, with 1171 and 815 documents respectively, indicating a substantial exploration into the chemical composition of *R. communis*. This research encompassed analyses of its various chemical constituents, including

oils, toxins, and secondary metabolites, and their potential applications in diverse fields. In parallel, Horticulture, represented by 953 documents, emphasized a keen interest in optimizing cultivation practices, indicating efforts to enhance yield, quality, and overall agricultural productivity of *R. communis*. The medicinal aspects of *R. communis* were also extensively explored, with Medicine and Traditional Medicine fields comprising 376 and 384 documents, respectively. This suggests a concerted effort to investigate its therapeutic properties and historical uses in traditional healing systems, alongside potential modern medical applications (Fig. 5). These findings emphasized the multidimensional nature of scholarly research, with a particular emphasis on traditional medicine, biology, and chemistry. The dataset reflected a rich tapestry of exploration across diverse fields, contributing to the collective understanding of these subjects.

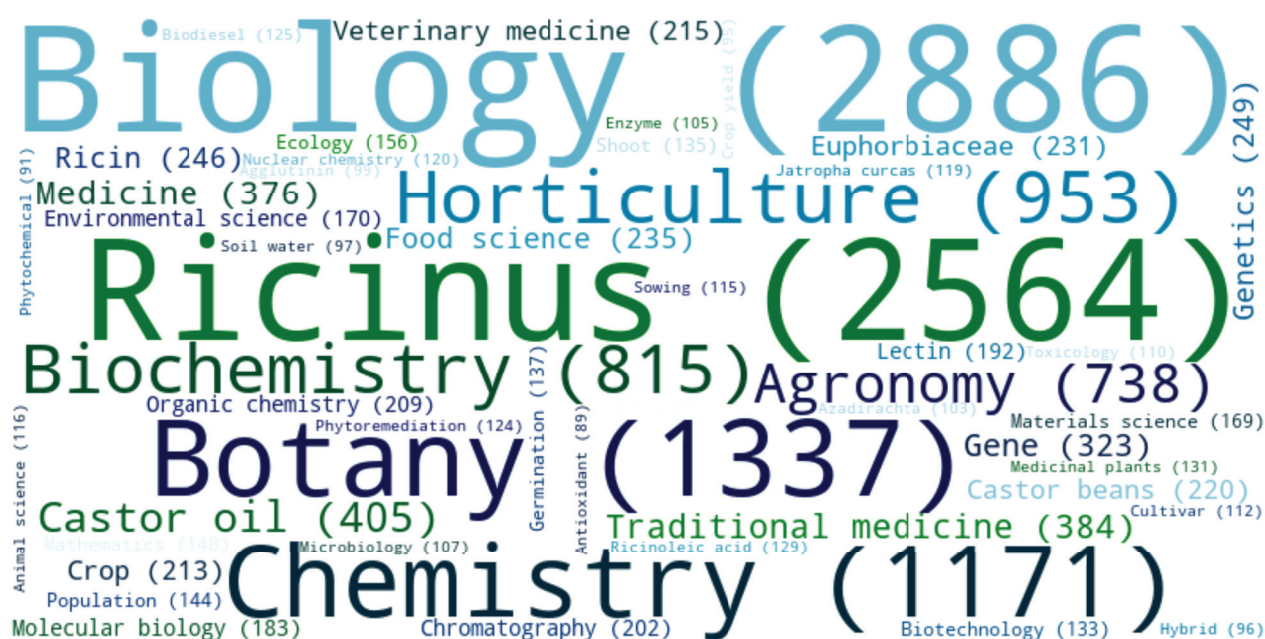


Fig. 5 Terms co-occurrence analysis within prominent terms

Research Collaboration Networks

Authors' Collaboration Network

The investigation involved a comprehensive analysis of 14,459 authors, exploring a substantial number of researchers within the specified subject domain. Author similarity was assessed through co-authorship, with a primary focus on their publications. The network included authors who had published at least 5 documents on *R. communis* and had a minimum citation count of 5 citations per document. The analysis identified 4 clusters within the network, illustrating interconnected and collaborative author groups. Clusters 1 and 2 comprised 10 and 8 authors, while clusters 3 and 4 consisted of two members each (Fig. 6).

John Browse emerged as the most prominent author, boasting the highest total link strength of 67, which underscores his influential role and extensive connections within the research community. Additionally, Wei Xu and Fenglan Huang have also distinguished themselves as leading figures, with total link strengths of 52 and 43, respectively. These findings reveal a diverse and dynamic research community characterized by varying degrees of specialization and collaboration. The varying link strengths highlight the breadth of expertise and the interconnected nature of the researchers, reflecting a robust network where individual contributions significantly impact the collective advancement of knowledge.

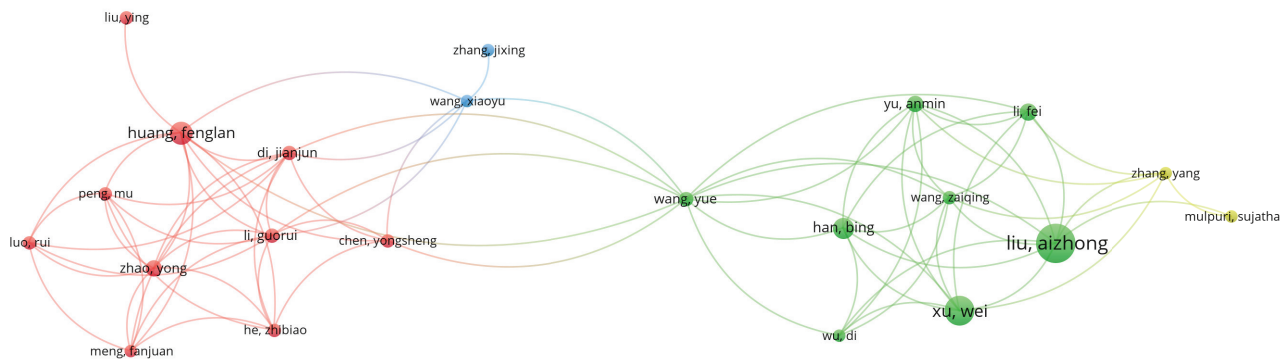


Fig. 6 Collaborative network among the authors on *R. communis*

Journal-wise Collaboration Network

The examination of collaboration among journals dedicated to *R. communis* research involved an analysis of a dataset comprising

1,785 journals, which revealed 174 interconnections among 38 journals through citation analysis. To be included in the network, journals had to meet specific criteria: publishing a minimum of 10 documents on *R. communis*, each receiving at least 10 citations.

This stringent criterion ensured the inclusion of influential and relevant journals, resulting in a network that identified 7 distinct clusters. Cluster 1 emerged as the largest, consisting of 10 journals, while clusters 2 and 3 each contained 6 journals. Clusters 4 included 5 journals, clusters 5 and 6 had 4 journals each, and cluster 7 comprised 3 journals (Fig. 7). These clusters highlighted thematic concentrations within *R. communis* research, indicating specific areas of scholarly focus. Among the clusters, "Industrial Crops and Products" demonstrated the highest connection strength at 254, underscoring its

pivotal role in fostering collaborative efforts within the research community. Additionally, the journals "Agronomy" and "Plant Physiology" exhibited prominent influence, with total link strengths of 29 and 25, respectively, as depicted in Fig. 7. This network analysis provides valuable insights into the thematic strengths and collaborative potential among journals engaged in *R. communis* research. By mapping these interconnections, the study contributes to a deeper understanding of the scholarly landscape, revealing the intricate web of collaboration and specialization that characterizes this field.

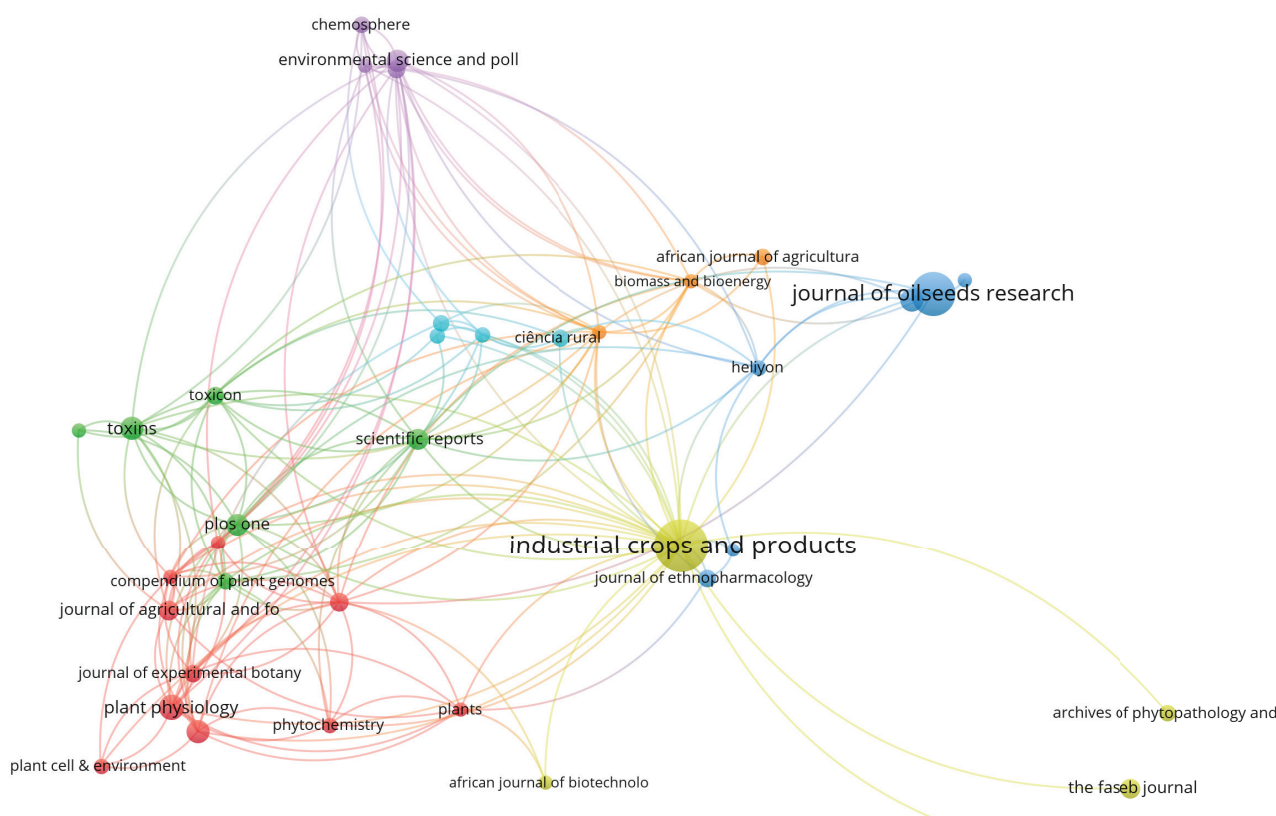


Fig. 7 Journal-wise collaboration network analysis on *R. communis* research

Organizational Collaborative Network

An investigation into the organizational collaboration network within the domain of *R. communis* research was undertaken using citation analysis. This comprehensive examination encompassed 2,975 organizations, elucidating relationships among 52 entities. The criteria for inclusion required each organization to have published a minimum of 12 documents and received at least 12 citations related to *R. communis* research. The resulting organizational collaboration network revealed 6 distinct clusters with a total of 618 connections (Fig. 8). Cluster 1, consisting of 22 organizations, emerged as the largest, showcasing a remarkable degree of inter-organizational cooperation. Clusters 2, 3, and 4 comprised 10, 8, and 6 organizations respectively, highlighting closely-knit connections among

them. Clusters 5 and 6 included 3 organizations each, demonstrating strong connections within these smaller groups. The Brazilian Agricultural Research Corporation exhibited the highest overall connection strength, with 553 links, indicating its pivotal role in the network. It was followed by the Western Regional Research Center and the Kunming Institute of Botany, which had 471 and 432 connections, respectively. Understanding this collaborative network is essential for fostering successful partnerships and advancing research on *R. communis*. Stakeholders such as researchers, institutions, and policymakers can gain valuable insights from these networks to strategically bolster collaborative efforts and propel research advancement. By identifying key players and examining the structure of inter-organizational relationships, the study provides a roadmap for enhancing cooperation and maximizing the impact of research initiatives in the field of *R. communis*.

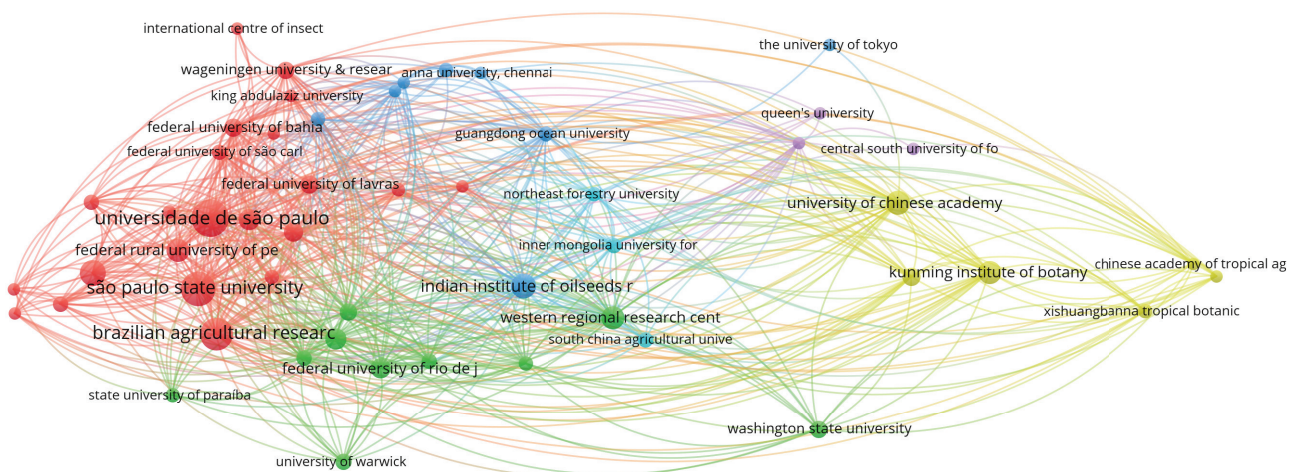


Fig. 8 Clusters of collaborative institutions for *R. communis* research

Country-wise Collaboration Network

In assessing country-wise collaboration networks within the domain of *R. communis* research, a comprehensive analysis was conducted involving 58 countries, which revealed 780 linkages. The inclusion criteria required each country to have published a minimum of 5 documents on *R. communis*, each with at least 5 citations. Through citation analysis, the study identified 7 distinct clusters, each characterized by varying levels of collaboration and research focus. Clusters 1, 2, and 3 comprised 15, 14, and 13 countries respectively, indicating significant collaboration within these groups. Clusters 4, 5, and 6 consisted of 8, 5, and 2 countries respectively, highlighting more

concentrated collaboration networks. Cluster 7 included only one country (Fig. 9). The analysis also showed that the United States and Brazil demonstrated the strongest connection strengths, with 2,552 and 2,031 links respectively, emphasizing their central roles in the collaborative network. This analysis underscores the importance of collaborative research in enhancing our understanding of *R. communis* by elucidating the global landscape and interconnectedness of scientific endeavors. It highlights how international partnerships can drive forward research in this field, providing valuable insights for researchers, institutions, and policymakers looking to foster and leverage global collaborations to advance knowledge and innovation in *R. communis* research.

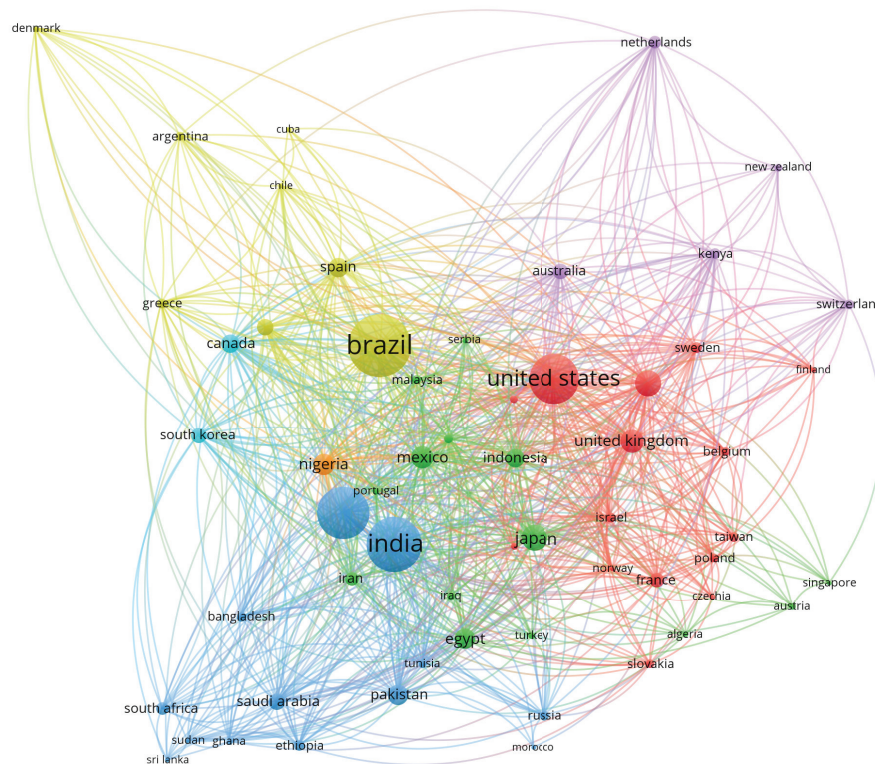


Fig. 9 Country-wise collaboration network in *R. communis* research

Conclusion

In the present study, the bibliometric analysis emphasized the research landscape surrounding *R. communis* L. from 2000 to 2023, providing a comprehensive understanding of its global imprint, collaborative dynamics, and scholarly impact. The analysis included 3862 articles authored by 2975 entities across 109 nations, involving 14459 authors, showcasing the breadth and depth of research efforts. The analysis revealed Brazil's prominent role as a key contributor with 520 documents and 7,521 citations. This indicates the nation's robust research community and significant academic influence, particularly demonstrated by institutions like the Universidade De São Paulo. Temporal trends highlight distinguished surges in scholarly output in 2010, as evidenced by citation analysis. Aizhong Liu emerged as a leading one among authors, and the Journal Industrial Crops and Products stands out as a pivotal platform for disseminating research in

this field. Furthermore, collaborative network analysis underscores the interdisciplinary nature of *R. communis* research, pointing towards fruitful opportunities for future collaborations and knowledge exchange. The identification of highly cited articles, active journals, and productive organizations serves as a roadmap for researchers, policymakers, and practitioners, facilitating informed decision-making and fostering continued advancement in the field. This bibliometric analysis not only offers valuable insights into the scholarly landscape of *R. communis* but also lays the groundwork for further exploration, collaboration, and innovation in this crucial area of study. It underscores the importance of continued research efforts and collaboration to address the challenges and harness the potential of *R. communis* for various applications.

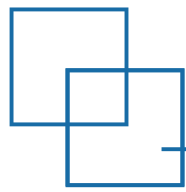
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CHAPTER
03

Soil Properties



INTRODUCTION

Soil is a complex matrix generated by the weathering of rocks that compose the Earth's crust's outer layer. It is generated through the dynamic interplay of minerals, organic matter, air, water, and other living species. It promotes plant growth due to its nature and the availability of nutrients. Plant development and yield are enhanced when the soil is nutrient rich (The State of Queensland, 2013). Soils, in addition to serving as a medium for plant growth, play an important role in gaseous exchange by absorbing and releasing gases such as carbon dioxide, oxygen, and methane. They can also hold water, which is an important resource for plant growth. Soils are host to various living organisms such as animals, fungi, bacteria, and other organisms because of their qualities. As a result of the presence of numerous living creatures, organic matter is constantly recycled through breakdown and accumulation. Soil also serve as a valuable basis for construction material from a commercial perspective (Soil Science Society of America, 2023).

Soil is made up of biotic and abiotic constituents, which comprise live creatures as biotic factors and minerals, organic matter, gas, and water as abiotic ones. All the components are responsible for plant growth and serve a significant role in preserving soil quality (Needelman, 2013). The percentages of each component vary amongst soil types, such as sandy, clayey, loamy, silty, and so on. The quantities of distinct components in soil are determined by the sites where the soil is available and the parent material from which it forms. The area where the soil is available and the parent material from which it forms determines the respective proportions of individual components in the soil. For instance, there are many different types of soils available in India. The first type is the alluvial soil which covers 46% of the Indian soil area. Rocks of the Himalayas are the parent material, and this kind of soil formation occurs by silt deposition by Indo-Gangetic-Brahmaputra Rivers. The next kind is the black soil which is formed from volcanic rocks in the Deccan Plateau. These soils are rich in clay and cover 16.6% of the total soil cover in India. The other types of soil include red and yellow soil, desert soil, laterite soil, peaty and marshy soil, alkaline soil, and mountain soil (Bhattacharyya et al., 2013).



The percentage composition, quantity, and quality of the components or nutrients in the soil all affect how fertile it is. The fertility of the soil in turn determines the type of crop that can grow in it and its yield and nutritional parameters. Ogundola et al., (2021) found different concentrations of essential oil from the shoots of *Solanum nigrum* L. that were grown in different types of soil. Due to the change in the oil content of the shoot, the free radical scavenging activity varied. It was reported in the study that plants grown of clay loam soil showed the highest radical scavenging activity. Similar results were obtained from extracts of plant shoots grown on clay loam soil for ABTS radical scavenging. Andrade et al., (2011) also reported a similar phenomenon in the case of *Piper dilatatum* Rich. They showed that the essential oil composition of plants collected from different regions of Amazon, Brazil during rainy seasons varied due to environmental variations including variations in soil type. Jimoh et al., (2019) reported that *Amaranthus caudatus* L. exhibited the highest phytochemical yield when grown in clayey loam soil. A similar thing was replicated for the antioxidant activity of the plant extract. Zargoosh et al., (2019) showed that the interaction of site and elevation played a significant effect on the antioxidant potential and total phenol content in *Scrophularia striata* Boiss. The antioxidative capacity was indirectly correlated to elevation, phosphorous, potassium, organic carbon, organic matter, and nitrogen levels for the first site. Similarly, the acidity content had the highest negative correlation with antioxidant capacity. The lime and sand percentage of soil was also negatively related to the phytochemical content.

It has previously been demonstrated that a plant's environment has an impact on the number of secondary metabolites it produces and, ultimately, on the phytochemical composition of that plant (Walker et al., 2001; Srivastava and Shym, 2002; Dorri et al., 2009). The temperature and the humidity of the area in which a plant grows affect the phytochemical profile of the plant (Fox et al., 1999). How the environment regulates phytochemical composition and quantity of plants is yet to be completely understood. Yet theories state that environmental factors may influence metabolic processes in plants which thereby affects the phytochemical content. At different altitudes, even the same plant shows different growth characteristics due to differences in light intensity, exposure to radiation, wind speed, humidity, water content in soil, and nutrient content in soils. The microbial composition of the soil may also affect the plant phytochemicals. Makgato et al., (2020) showed that inoculation of beneficial soil microbes like *Rhizobium* into soil can also stimulate plant phytochemical content. They showed that total phenolic

and flavonoid content increased because of *Rhizobium* inoculation in soil as compared to control. This occurred even though plant biomass and nitrogen fixation did not show any increase. Similarly, Egamberdieva et al., (2015) have reviewed in their book that Plant Growth Promoting Rhizobacteria helps plants by improving their salt and heavy metal tolerance, preventing plant diseases, and boosting soil fertility. In the case of medicinal plants specifically, they can enhance the phytochemical levels by inducing secondary metabolite production. It is thus beneficial to enrich soils with beneficial microbes which can further be utilized for commercial purposes. Thus, it is evident that environmental variations including humidity, temperature, radiations as well and soil microbiomes influence the secondary metabolite production of medicinal plants and hence their phytochemical production. These attributes are beneficial to understanding plant physiology and the best possible conditions for the cultivation of medicinal plants. In the current study, emphasize on studying the physicochemical variations in soil quality from different altitudes of sampling sites is given in Table 2. Soil physicochemical parameters like pH, electrical conductivity, organic carbon content, available nitrogen, phosphorous, potassium, sulphur and micronutrients, total moisture content, heavy metal, and bulk density have been studied to understand the quality at different altitudes and how they may influence vegetation in the different sites.

Sampling Sites

The bulk soil and plants (along with the rhizospheric soil) were collected from a total of 26 sites. The numbering of the sites, name

Table 1 Study sites and coordinates

S.No.	States	Site	Site Code	Latitude	Longitude
1.	Uttarakhand	Gomukh	UK -S1	30.56790	79.03081
2.		Gangotri	UK-S2	31.03920	78.74655
3.		Uttarkashi	UK-S3	30.74619	78.48377
4.		Devprayag	UK-S4	30.1358	81.1218
5.		Haridwar	UK-S5	29.9169	81.5315

S.No.	States	Site	Site Code	Latitude	Longitude
6.	Uttar Pradesh	Bijnor	UP-S1	29.2857	82.3243
7.		Narora	UP-S2	28.1465	83.1315
8.		Badaun	UP-S3	27.9394	83.5612
9.		Farrukhabad	UP-S4	27.4104	84.496
10.		Bithoor	UP-S5	26.6159	85.1242
11.		Dalmau	UP-S6	26.3485	85.5979
12.		Prayagraj	UP-S7	25.2537	86.2076
13.		Mirzapur	UP-S8	25.8588	87.0908
14.		Varanasi	UP-S9	25.1518	87.396
15.		Ballia	UP-S10	25.3546	87.9107
16.	Bihar	Revelganj	BH-S1	25.4388	88.2213
17.		Patna	BH-S2	25.3808	88.3809
18.		Barh	BH-S3	25.2311	88.3895
19.		Bahachoki	BH-S4	25.1782	88.1959
20.		Farka	BH-S5	25.2323	78.8535
21.	Jharkhand	Sahibganj	JH-S1	25.1461	79.6282
22.	West Bengal	Farraka	WB-S1	24.8227	80.277
23.		Hazarduari	WB-S2	23.9969	81.1218
24.		Mayapur	WB-S3	23.4129	81.5315
25.		Hoogly	WB-S4	22.8491	82.3243
26.		Gangasagar	WB-S5	22.1774	83.1315

The temperature of a particular site is dependent on its altitude as well as climate conditions. At the time of sample collection, the temperature of the sites as well as altitude

of the sites as shown in live GPS map via GPS map camera app was noted down. The altitude and temperature of different sites for sample collection are shown in the Table 2.

Table 2 Temperature and altitude of different sampling sites

Site	Temperature (°C)	Altitude (m)
UK -S1	09	3794
UK -S2	17	2506
UK -S3	18	1232
UK -S4	23	1014
UK -S5	34	265
UP-S1	29	217
UP-S2	31	179
UP-S3	25	162
UP-S4	27	136
UP-S5	28	113
UP-S6	31	91
UP-S7	33	91
UP-S8	32	91
UP-S9	38	65
UP-S10	34	67
BH-S1	25	69
BH-S2	25	36
BH-S3	28	30
BH-S4	30	18
BH-S5	25	23
JH-S1	25	17
WB-S1	28	32
WB-S2	30	14
WB-S3	27	8
WB-S4	30	9
WB-S5	31	3

Soil Analysis

Physicochemical Analysis of Soil

Total Moisture Content (%)

Soil moisture content, often known as water content, is an indication of the quantity of water in the soil. Moisture content is stated as a proportion of the mass of water contained in the pore spaces of soil to the solid mass of particles in that substance. The mass of the sample is determined using a reference temperature of $110 \pm 5^\circ\text{C}$. Almost, all soil tests detect the natural moisture content of the soil, which is critical knowledge for all soil mechanics. The natural moisture content indicates the condition of the soil in the field (Hossain et al., 2022).

Apparatus and equipment required: Non-corrodible vented container, thermostatically controlled drying oven that maintains temperatures between 105°C to 115°C , Balance of sufficient sensitivity (sensitive to 0.01 g) and container handling apparatus.

Procedure

1. Clean, dry and weigh W_1 the container. The balance needs to be tared before it is used to measure the weight.
2. Weigh W_2 a sample of the specimen in the container.
3. Keep the container in the oven for 24 hours. Dry the specimen to a constant weight, maintaining the temperature between 105°C to 115°C (The time will vary with the

type of soil, but 16 to 24 hours is usually sufficient)

4. Record the final constant weight W_3 of the container with the dried soil sample. Peat and other organic soils should be dried at a lower temperature (approximately 60°C) for a longer period.

Calculations

1. Weight of the container = W_1 g
2. Weight of the container + Weight of the wet sample = W_2 g
3. Weight of the container + Weight of the dried sample = W_3 g
4. Weight of water in the soil sample = $W_2 - W_3 = M_w$ g
5. Weight of the dry soil = $W_3 - W_1 = M_s$ g
6. Moisture content in the given soil sample = $(M_w \text{ g} / M_s \text{ g}) \times 100\%$

Bulk Density

Bulk density is a commonly measured soil property by agriculturalists and engineers. High bulk density soils are soils with little pore space, so water infiltration is reduced, root penetration is inhibited, and aeration is restricted – reducing agricultural productivity. Low bulk density soils are easily compacted and may settle considerably to the detriment of roads, sidewalks, and building foundations (Bowen, 2016).

Apparatus and equipment required: Top load balance, soil spatula, 100 ml graduated

measuring cylinder, 2×50 ml beaker, paper towels and mud bucket.

Procedure

1. Add slightly more than 50 ml of the soil sample to 50 ml beaker.
2. Clean and thoroughly dry a 100 ml graduated cylinder. Weigh and record weight (A).
3. Slowly add soil sample to pre-weighed graduated cylinder to the 10 ml line. Compact the soil by dropping onto a padded surface like a book, notebook, etc. at least ten times from a height of about 2-3 inches.
4. Repeat this process in 10 ml intervals until you reach the 50 ml mark.
5. Use a soil spatula to level the top of the sample in the graduated cylinder and add soil with the spatula until the top of the soil sample is exactly even with the 50 ml line – this is the bulk volume of compacted soil (B) ($1 \text{ ml} = 1 \text{ cm}^3$).
6. Weigh and record graduated cylinder plus compact soil weight (C).
7. After drying the beaker, place any soil sample that is still in it back into the sample storage container.
8. Return 50 ml sample in graduated cylinder to 50 ml beaker. Remove all of sample within graduated cylinder.
9. Slowly pour approximately 25 ml of soil sample from beaker into water in the graduated cylinder. Gently stir soil/water mixture to remove any air bubbles. Add the second 25 ml of soil sample and stir again to remove air bubbles.

Calculations

1. Weight of 100 ml graduated cylinder = A
2. Bulk volume of the compacted soil = B
3. Weight of cylinder + compacted soil = C
4. Weight of soil sample = $C - A = D$
5. Bulk density (g/cm^3) = D/B

pH

Principle: The pH of sample is measured with a pH meter, in which the potential of a hydrogen ion indicating electrode (glass electrode) is potentiometrically measured against a calomel saturated reference electrode, which also functions as a salt bridge. Most pH meters now contain a single integrated electrode. The equipment must be calibrated with a standard buffer solution of known pH before measuring the pH of the soil. As temperature affects pH, the pH meter is set according to the temperature of the solution (Varley, 1972; Jackson, 1973).

Reagents: Buffer solutions (pH 4.0, 7.0, and 9.2)

Equipment required: A balance, 100 ml beaker, measuring cylinder, glass rod, pH meter and ordinary tissue paper.

Procedure

1. 25 g of the soil was weighed in a 100 ml beaker and make it to 50 ml final volume by adding distilled water. The mixture was stirred well for at least four times within a 30-minute period to allow the soil and water to reach equilibrium.
2. In the meantime, the pH meter was switched on.

- Initially the instrument was calibrated with buffer solution of known pH 4, 7.0, and 9.2.
- The electrodes were washed with distilled water and wiped dry with a tissue paper.
- Then, the electrode was dipped in the sample and the readings were taken.
- Finally, the electrodes were washed with distilled water and placed back into a beaker containing 4.00-7.00 pH buffer or 3-4M KCl.

Interpretation

pH	Category	Soil Rating/Recommendation
<6.5	Acidic	Requires liming for reclamation.
6.5-8.7	Normal	Optimum for most crops
8.8-9.3	Alkaline	Requires application of organic manures
>9.3	Alkali (Sodic)	Requires gypsum for amelioration

Electrical Conductivity

Principle: A conductivity meter known as “Solu Bridge” is used to measure the electrical conductivity of a soil solution. It is based on the Wheat Stone Bridge principle, in which alternating current is utilized instead of direct current to prevent electrode polarization and electrolysis of the solution. In a branched circuit with the conductance cell having resistance R_x , two fixed resistances R_1 and R_2 and a variable resistance (R_v) are linked. The variable resistance (R_v) is adjusted until no current flows through it and the reading is taken. The resistance or conductance (R_v) is measured (Richards, 1954; Chopra and Kanwar, 1976).

Apparatus and equipment required: Weighing balance, 100 ml beaker, measuring cylinder, glass rod and conductivity meter.

Procedure

- 25 g of the soil samples were taken in a 100 ml beaker.
- Added 50 ml distilled water.
- Intermittent stirring was done with a glass rod for 30 minutes.
- The samples were left overnight to obtain a clear supernatant.
- The conductivity of the supernatant liquid was determined with the help of a conductivity meter.

Interpretation

EC (1:2 soil water; $\mu\text{S/m}$)	Soil Rating
Below 800	Normal.
800 - 1600	Critical for salt sensitive crops.
1600 - 2500	Critical for salt tolerant crops.
Above 2500	Injurious to all crops.

Organic Carbon

Principle: In the presence of concentrated sulphuric acid, a known weight of soil was treated with an excess of standard potassium dichromate solution. The heat of the sulphuric acid gently digests the soil at a low temperature, oxidizing the organic carbon in the soil to CO_2 . The excess potassium dichromate was titrated against a standard solution of ferrous ammonium sulphate in the presence of a diphenylamine indicator and sodium fluoride or phosphoric acid, which distinguishes the colour due to their flocculating effect. The hue of the suspension varies from violet to blue to vivid green at the terminal point (Walkley and Black, 1934; Jackson, 1973).

Chemicals and reagents used

1. Potassium dichromate solution (1 N $\text{K}_2\text{Cr}_2\text{O}_7$): 49.04 g of analytical grade $\text{K}_2\text{Cr}_2\text{O}_7$ was dissolved in distilled water and the volume was made up to 1 litre.
2. Concentrated sulphuric acid (H_2SO_4).
3. Orthophosphoric Acid (85%) or sodium fluoride (NaF).
4. Diphenylamine indicator: 0.5 g diphenylamine indicator was dissolved in a mixture of 100 ml concentrated sulphuric acid and 20 ml distilled water. This was stored in an amber colour bottle.
5. Ferrous ammonium sulphate solution [0.5 N, $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$]: 392 g analytical grade ferrous ammonium sulphate was dissolved in distilled water, to which 15 ml concentrated sulphuric acid was added and volume made up to 2 litres with distilled water.

Apparatus required: 250 ml Erlenmeyer (Conical) flask, pipette, burette and measuring cylinder.

Procedure

This process is also known as Walkley and Black's rapid titration method (1934).

1. 2 gm of dried, ground, and sieved soil was taken in a 250ml conical flask.
2. To it, 10 ml 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ solution was added and shaken gently to mix the contents.
3. Next, 20 ml of concentrated sulphuric acid was added while swirling the flask slowly as the reaction is exothermic and a lot of heat is produced.
4. The flask was kept on a dry tile or asbestos sheet for 30 minutes and left to attain room temperature.
5. After cooling, about 0.5 g of NaF or 5 ml orthophosphoric acid, 100 ml of distilled water and 10 drops of diphenylamine indicator solution were added. These were shaken vigorously for complete mixing.
6. This was titrated against N/2 ferrous ammonium sulphate solution till the colour changes from violet to bright green through blue.
7. The volume of ferrous ammonium sulphate solution used for titration was noted down every time.
8. A blank titration was carried out without any soil.

Calculations

1. Weight of soil taken (W) = 2 g
2. Vol. of N/2 ferrous ammonium sulphate

- used for blank titration = X ml
- Vol. of N/2 ferrous ammonium sulphate used to titrate excess nascent oxygen = Y ml
 - Vol. of 1N $K_2Cr_2O_7$ used for oxidation of organic carbon in soil = $(X-Y)/2$ ml
 - 1 ml of 1N $K_2Cr_2O_7$ = 0.003 g C
 - % Organic Carbon in Soil = $X-Y/2 \times 0.003 \times 100/W$

Interpretation

Organic Carbon (%)	Soil Rating
<0.4	Low
0.4-0.75	Medium
>0.75	High

Available Nitrogen

Principle: An excess of alkaline potassium permanganate is applied to a known weight of soil, extracting a relatively easily oxidizable fraction of organic nitrogen. Ammonia is absorbed in excess of boric acid, forming ammonium borate, which is titrated against standard acid to determine the amount of ammonium absorbed (Subbaiah, 1956).

Chemicals and reagents required

- Potassium permanganate solution ($KMnO_4$): 3.2 g/l of potassium permanganate was dissolved in distilled water and the volume was made up to 1 litre.
- Sodium hydroxide solution (NaOH): 25 g/l of sodium hydroxide pellets were dissolved in distilled water and the volume was made up to 1 litre.
- 0.02 N sulphuric acid (H_2SO_4).
- Mixed indicator: 0.066 g of methyl red and 0.099 g of bromocresol green were mixed in 100 ml of ethanol.

- Boric acid: 25 g/l of boric acid was dissolved in one litre of distilled water and to it 40 ml mixed indicator was added. Then, the pH was adjusted to 4.5-5.0 by adding 2.5 % NaOH.

Apparatus and equipment required: Kjeldahl distillation assembly, measuring cylinder, burette, balance, pipettes, and 100 ml conical flask.

Procedure

- The Kjeldahl assembly was prepared by dipping the respective inlet tubes, one in 0.32% $KMnO_4$ and second in 2.5% NaOH reagent tanks.
- 5 g soil sample was weighed and put into distillation tube carefully so that the soil sample does not stick to the sides of the tubes. Soil particles attached to the sides of the tube were washed down with distilled water.
- The distillation tube was fixed in distillation unit and the sample was moistened with distilled water by pressing the dilution key.

4. 25 ml of 2.5% boric acid was taken in a conical flask and the receiving end of the distillation tube was dipped in it.
5. Next, 25 ml of KMnO_4 and 25 ml NaOH were added in the sample by pressing the respective keys.
6. The heating unit was switched on, and the process ran for 6 minutes.
7. The ammonia gas released from the sample was distilled and collected into the receiver containing acid. After complete digestion, the receiver flasks were removed.
8. The ammonium borate formed in the receiver flask was titrated against 0.02 N

H_2SO_4 acid and note the volume of 0.02 N H_2SO_4 utilized. The colour changes from bluish green to wine red.

Calculations

1. Weight of soil taken = 5 g
2. Vol. of 2.5% boric acid taken = 25 ml
3. Vol. of 0.02 N H_2SO_4 used to titrate ammonium borate = X ml
4. 1 ml of 0.02 N H_2SO_4 = 0.00028 g of N
5. Available N (%) = 0.00028 g of N
6. Available N (ppm) = percentage N $\times$ 10,000
7. Available N (Kg/ha) = ppm $\times$ 2.24

Interpretation

Available Nitrogen (kg/ha)	Soil Rating
<272	Low
272-544	Medium
>544	High

Available Phosphorous

Principle: The activity of Ca^{2+} in the soil solution and the pH of the soil regulates the solubility of calcium phosphate in it. The bicarbonate (HCO_3^-) activity in the soil is increased by the 0.5 M NaHCO_3 solution buffered to pH 8.5, which reduces calcium activity. As a result, some phosphate from the surface of calcium phosphate gets dissolved in the soil. Similarly, due to the inactivation of Al and Fe, NaHCO_3 solution removes some phosphorous from Al and Fe phosphates. The precipitation of phosphate released from calcium phosphate is prevented by low Ca^{2+} activity. The soluble

phosphate forms heteropoly complexes with molybdate ion freed from ammonium molybdate solution when added to the soil extract. (Bray and Kurtz, 1945; Black, 1965).

Chemicals and reagents required

1. Standard phosphorous solution
 - i. Standard solution of P (100 ppm): 0.4387 g of KH_2PO_4 was dissolved in distilled water and the volume was made up to 1 litre.
 - ii. Standard solution of P (5 ppm): 5 ml of 100 ppm P solution was diluted to 100 ml with distilled water.

2. 0.5 M NaHCO_3 : 42 g of NaHCO_3 was dissolved in distilled water and the volume was made up to one litre after adjusting the pH to 8.5 with sodium hydroxide using a pH meter.
3. Sulphuric acid (5N): 139 ml of concentrated H_2SO_4 was diluted to 1 litre.
4. Reagent A: Dissolve 12 g of ammonium paramolybdate in 250 ml distilled water. Separately, 0.2908 g of potassium antimony tartrate ($\text{KSbO} \cdot \text{C}_4\text{H}_4\text{O}_6$) was dissolved in 100 ml of distilled water. Both these dissolved reagents were added to 1 litre of 5 N sulphuric acid. Both were mixed thoroughly and diluted with distilled water to 2 litres.
5. Reagent B: 1.056 g of L-ascorbic acid was dissolved in 200 ml of reagent A and mixed. It was prepared freshly before use.

Apparatus and equipment required: 100 ml conical flasks, funnels, pipette, (1 and 5 ml), 25 ml volumetric flasks, 100 ml measuring cylinder, electric shaker, Whatman No. 1 filter paper and spectrophotometer.

Procedure

a) Preparation of a standard curve

The relationship between the intensity of the coloured solution of a substance and the percent transmittance or absorbance of the light rays flowing through the solution was depicted by a standard curve. It was used to figure out how much of a certain element is present in an unknown sample. 0, 0.5, 1, 2, 3, 4, 5 ml of P solution was taken in seven different 25 ml

volumetric flasks to make the standard curve. It will produce a solution with a final concentration of 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 0.1 ppm, respectively. To it, 5 ml of extracting solution and 0.5 ml 5N H_2SO_4 were mixed and shaken well until the evolution of CO_2 stopped. 10 ml of distilled water was added while washing the neck of the flask and 4 ml of reagent B and the volume was made up to the mark with distilled water and mixed. All flasks developed a blue colour of variable intensity. The intensity of blue colour was read on spectrophotometer at 880 nm. A standard curve was plotted using P concentration against absorbance value to establish their relationship.

b) Analysis of the test sample

- 1) 1 g of soil sample was taken in a 100 ml flask.
- 2) To it, a pinch of Darco-G 60 and 20 ml of 0.5 N NaHCO_3 solution were added.
- 3) The flask was placed on an electric shaker and mixed at a constant speed for half an hour. Then the contents were filtered through Whatman No. 1.
- 4) A blank was prepared by following all the steps without addition of soil.
- 5) In case, the filtrate was not clear, a pinch of Darco – G was added.
- 6) 5 ml of the filtrate was taken in a 25 ml volumetric flask and proceed further for colour development as described under preparation of standard curve.

Calculations

1. Weight of soil sample taken = 1 g
2. Vol. of 0.5N NaHCO_3 solution added = 20 ml
3. First dilution = 20 times
4. Vol. of the filter taken for colour development = 5 ml
5. First volume made = 25 ml
6. Second volume = 5 times
7. Total dilution = $20 \times 5 = 100$ times
8. Concentration of P from spectrophotometer = X AU (absorbance units)
9. Available P in soil (ppm) = $X \text{ (AU)} \times 100$
10. Available P (Kg/ ha) = $\text{ppm} \times 2.24$

Interpretation

Available Phosphorus (kg/ha)	Soil Rating
>12.4	Low
12.4-22.4	Medium
22.4-50	High
>50	Very High

Available Potassium

Principle: In a neutral normal ammonium acetate solution, a known weight of soil was shaken. Potassium (K) ions absorbed on soil colloids exchange ammonium ions. The amount of exchangeable and water-soluble potassium in the extract was measured using a flame photometer. The transfer of non-exchangeable K to exchangeable form was hampered during ammonium acetate extraction because ammonium ions, like K^+ , retain strongly charged layers together (Merwin and Peech, 1951; Black, 1965; Jackson, 1973).

Chemicals and reagents required

1. Neutral normal ammonium acetate solution ($\text{CH}_3\text{COONH}_4$): 77.09 g/l of ammonium acetate was dissolved in distilled water and the volume was made up to 1 litre. The pH of the solution was

adjusted to 7 with ammonium solution or acetic acid.

2. Standard solution of K (1000 ppm K): 1.91 g of potassium chloride (KCl) was dissolved in distilled water and the volume was made to 1 litre.
3. Working standard solution of K: The stock solution was diluted 100 times to get 10 ppm K solution.

Apparatus and equipment required: A weighing balance, 150 ml conical flasks, a shaker, funnels, beaker, Whatman filter paper No 1, pipettes and a flame photometer.

Procedure

1. 5 g of soil was weighed in a 150 ml conical flask.
2. To this, 25 ml of neutral normal ammonium acetate solution was added.
3. The mixture was shaken for 5 minutes

on an electric shaker and then filtered through Whatman No. 1 filter paper.

4. 5 ml of the filtered extract was taken in a 25 ml volumetric flask and the volume was made up with distilled water. This solution was fed into the atomizer of the flame photometer and readings were noted down.

The amount of K in the test sample was calculated by using the dilution factor.

Interpretation

Available Potassium (kg/ha)	Soil Rating
<137	Low
137– 337	Medium
>337	High

Available Sulphur

Principle: Soil was shaken with 0.15 % CaCl_2 solution. During extraction, chloride ions displace adsorbed sulphate while calcium ions decrease soil organic matter extraction and hence eliminate contamination caused by extractable organic sulphur. The turbidity produced by the precipitation of sulphate as barium sulphate is measured on a spectrophotometer at a wavelength of 420 nm. The turbidity is stabilized using gum acacia solution, which prevents the barium sulphate formed from settling (Lisle et al., 1994).

Chemicals and reagents required

1. Extracting solution (0.15% CaCl_2): 1.986 g of calcium chloride dihydrate ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) was dissolved in distilled water and volume made up to 1 litre.

Calculations

1. Weight of soil sample taken = 5 g
2. Volume of the neutral normal $\text{CH}_3\text{COONH}_4$ solution added = 25 ml
3. Dilution = 5 times
4. Reading of K (ppm) in flame photometer = Y
5. In ppm K = $Y \times \text{total dilution} - A$
6. In kg/ha = $A \times 2.24 - C$

2. Barium chloride (BaCl_2)
3. Gum acacia solution (0.25%): 0.25 g of gum acacia was dissolved in distilled water and diluted to 100 ml.
4. Standard sulphur solution (100 ppm): 0.5434 g of the reagent grade potassium sulphate (K_2SO_4) was dissolved in distilled water and diluted to 1 litre.

Apparatus and equipment required: 150 ml conical flask, funnel, pipettes, 25 ml volumetric flasks, electric shaker, and spectrophotometer and Whatman No. 42 filter paper.

Procedure

a) Preparation of standard curve:-

1. 0.25, 0.5, 1.0, 2.5 and 5.0 ml of 100 ppm S solution were taken in different 25 ml volumetric flasks. It was theoretically

calculated to give 0, 1, 2, 4, 7, 10, 20 ppm concentration of sulphur in the final volume.

2. To every flask 10 ml 0.15% CaCl_2 solution and 1 g BaCl_2 were added.
3. Mixed for 1 minute to dissolve all the crystals.
4. Next, 1ml 0.25% solution of gum acacia was added.
5. The volume was made up to the mark for all the flasks and shaken properly for thorough mixing. Within 5-30 minutes after the development of turbidity, the standards were read on a spectrophotometer at 420 nm.
6. 0 absorbance at 0 ppm solution (blank) was adjusted.
7. A standard curve was plotted showing relationship between concentration of S (turbidity) and transmittance/absorbance readings.

b) Analysis of test samples:-

1. 10 g air dried soil was weighed and transferred to a 150 ml conical flask.

2. 50 ml of 0.15% CaCl_2 solution was added, and the mixture was shaken for 30 minutes on an electric shaker.
3. Filter the suspension through Whatman No. 42 filter paper.
4. 20 ml of the filtrate was taken in a 25 ml volumetric flask and the same steps as in case of standard curve were followed.
5. A blank was run with all the chemicals except the soil.
6. The sulphate concentration of unknown samples was determined from the standard curve.

Calculations

1. Weight of soil taken= 10g
2. Volume of extractant added= 50 ml
3. First dilution= 5 times
4. Volume of aliquot taken= 20 ml
5. Final volume= 25 ml
6. Second dilution= 1.25 times
7. Total dilution= $5 \times 1.25 = 6.25$ times
8. ppm of S from standard curve= Y
9. ppm of S in soil= $Y \times 6.25$
10. S in kg/ha= ppm of S $\times 2.24$

Interpretation

Available Sulphur (ppm)	Soil Rating
<10 ppm	Deficient
>10 ppm	Sufficient

Heavy Metal

All the heavy metal i.e. Cr, Ni, As, Sr, Cd, Hg and Pb, are extracted with the help of ICP-MS (Make-Thermo Scientific instrument) (Retka et al., 2010).

Procedure

1. Take the sample and homogenize properly.
2. Take approximately 0.1 to 0.2 g sample in microwave vessels and add 4 ml of HNO_3 (Suprapure grade) add 1 ml of H_2O_2 (Suprapure grade).
3. Kept at room temperature 20-30 minutes for open digestion.
4. Afterwards samples were put in microwave for close digestion.
5. After digestion, samples were transferred into the 50 ml volumetric flasks and volume make up to the mark.
6. Samples were vortexed properly and run of ICP-MS against the linearity.

Calculations

Calculate the concentration of the elements as follows.

Sample Conc. = (Sample reading - reagent blank reading $\times$ dilution factor) / Sample Wt.

Micronutrient

Principle: All the four micronutrient cations i.e. Zn, Mn, Fe and Cu, are extracted by shaking the soil with DTPA extracting solution containing 0.005M DTPA, 0.1 M TEA (Triethanol amine) and 0.01 M $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ buffered at pH 7.3. During this extraction, TEA gets protonated as HTEA^+ because of

which micronutrient cations from the solid phase comes into solution and are chelated by the DTPA. Buffering of the extractant in the slightly alkaline pH range and inclusion of soluble Ca^{2+} through $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ helps avoiding dissolution of CaCO_3 and thus excludes from the estimation of the occluded micronutrients, which do not form a part of the pool that is available for absorption by plant roots. After that the contents of the micronutrients cations in the soil extract are estimated on atomic absorption spectrophotometer (Katyal and Sharma, 1991).

Chemicals and reagents required

1. DTPA extraction solution: This solution was prepared to contain 0.005M DTPA, 0.01M CaCl_2 and 0.1M TEA (Triethanolamine) and its pH was adjusted to 7.3. For preparing one litre of this solution, 13.3 ml $(\text{HOCH}_2\text{CH}_2)_3\text{N}$ i.e. TEA, 1.967 g DTPA and 1.47 g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ were dissolved in about 500 ml of deionized water. Sufficient time was given for DTPA to dissolve, and the contents are diluted to approximately 900 ml. The pH of the solution was then adjusted to 7.30 ± 0.05 by adding 6N HCL while stirring and finally the contents were diluted to 1 litre. This solution was stable for several months.

Apparatus and equipment required: 1 litre volumetric flask, 100 ml narrow mouth polyethylene bottles, pipettes, electric shaker, Whatman No. 1 filter paper and atomic absorption spectrophotometer.

Procedure

1. 12.5 g of air-dried soil sample was taken and transferred to a 100 ml narrow mouth polyethylene bottle.
2. 50 ml DTPA solution was added, and the bottle was closed with the stopper.
3. The bottle was shaken on an electric shaker for 2 hours at 25°C.
4. The contents were then filtered through Whatman No. 42 filter paper to obtain a clear solution.

5. Also, a blank was run with only DTPA solution without the soil.

Calculations

1. Weight of soil used for extraction= 12.5 g
2. Volume of the extractant used= 50 ml
3. Dilution= 2 times
4. Concentration of the given micronutrient in extract= A mg/kg
5. Available micronutrient in given soil sample= $A \times 2$ mg/kg

Interpretation

Content below which the soil is deficient	
Metal	mg/kg soil
Zn	0.6
Cu	0.2
Fe	4.5
Mn	3.5

Rhizosphere Soil Microbiology

Principle: The principle for the analysis of microbe's different media is used such as nutrient agar, Eosin Methylene blue, MacConkey agar, Azotobacter, Azospirillum, Rhizobium, zinc solubilising, phosphate solubilising and potash mobilizer. The microbial count is usually expressed in CFU (colony-forming units) per gram or millilitre. The direct count method for enumerating bacteria in natural environments is widely used [Kirchman, 1982].

Procedure

- Different growth medium is used to grow different types of microorganisms is given in Table 3.

- The medium is sterilized in an autoclave.
- Petri dishes are used to hold the growth media.
- A small number of bacteria is needed to inoculate the growth media.
- A 100 μ l culture of sample is picked up with the help of pipette and transferred to the growth media and spread with the help of L-shaped spreaders.
- The inoculated growth media is incubated at the optimal temperature and conditions for the bacteria to grow.
- After incubation, the bacterial growth can be observed by looking closely at the colonial growth on the surface of a solid medium.

Table 3 Lists the various growth media that are used to cultivate the various kinds of microorganisms.

Serial No.	Target Organism	Synthetic Media Used	Make
1.	Total Bacterial Count	Nutrient Broth	HiMedia (M002-500G)
2.	Total Fecal Count	MacConkey Agar	HiMedia (M008S-500G)
3.	Total Coliform Count	Eosin methylene Agar	HiMedia (M317-500G)
4.	Potash Mobilizer	Aleksandrow	HiMedia (M1997-500G)
5.	Zinc Solubilizer	Zinc sulphate	HiMedia (M2023-500G)
6.	<i>Rhizobium</i>	Rhizobium	HiMedia (M408-500G)
7.	<i>Azotobacter</i>	Azotobacter	HiMedia (M1944-500G)
8.	<i>Azospirillum</i>	Azospirillum + KOH	HiMedia (M1720-500G + M1720-500G)
9.	Phosphate Solubilizes	Pikovskaya	HiMedia (GM1719-500G)

Apparatus and equipment required: Weighing balance, spatula, distilled water, measuring cylinder, and a 1000 ml conical flask.

Calculation

- Colony forming Units (CFU/ml) = Number of colonies × Dilution factor/volume of culture

Correlation Studies and Statistical Analysis

The tests have been performed in triplicates and the mean of values along with the standard deviation has been represented graphically. A total of 8 parameters have been studied for 26 sites and each parameter has shown considerable variation. The effect of one parameter on the other may be studied

through correlation. A correlation coefficient is an indicator of the relationship between two variables. The correlation coefficient is a statistical measure that indicates the strength and direction of the relationship between two variables. Its value ranges from -1 to +1, representing different degrees and types of correlation. When the correlation coefficient is closer to +1, it signifies a strong positive relationship between the variables. This means that as one variable increases, the other tends to increase as well. A correlation coefficient around 0 implies no linear relationship between the variables. Changes in one variable do not predict or affect changes in the other. As the correlation coefficient approaches -1, it denotes a strong negative relationship. This suggests that as one variable increases, the other tends to decrease.

Results and Discussion

Physicochemical Characterization of Soil

Moisture content is one of the most essential index qualities for determining the relationship between soil behaviour and index values. Soil moisture content expresses the phase

relationships of water, air, and solids in each volume or weight of material. The consistency of a specific soil, combined with its liquid and plastic limitations, is used to represent its relative consistency in cohesive soil (Hossain et al., 2022). The moisture content of different sampling sites is shown in Fig. 1

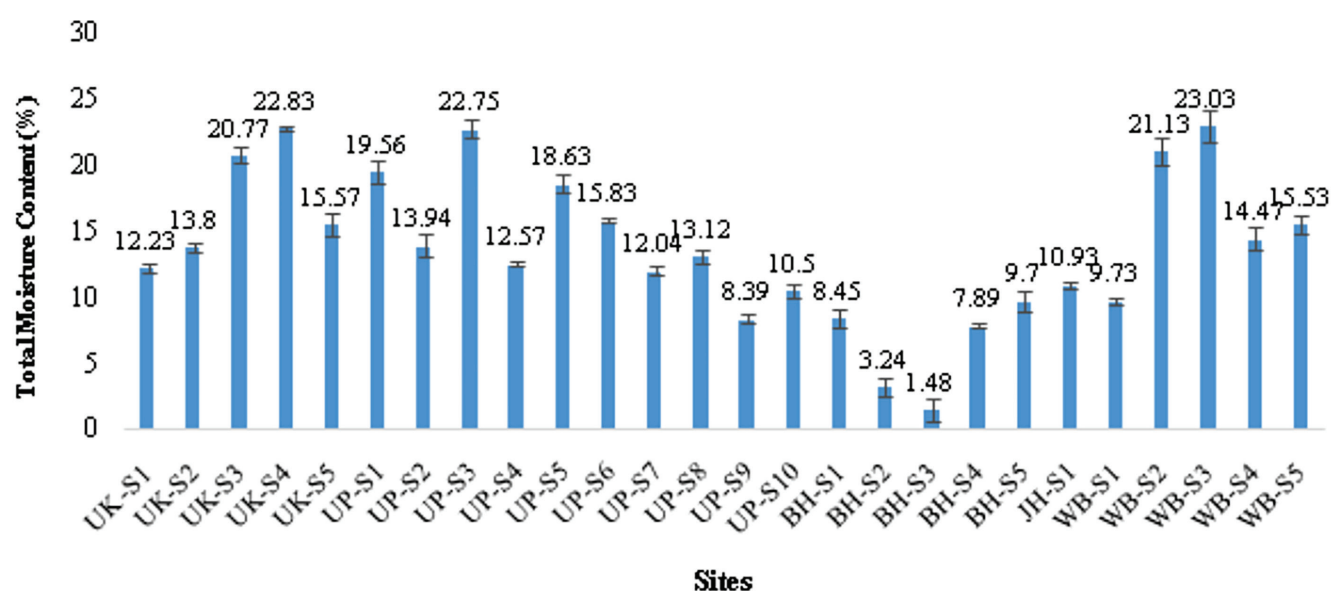


Fig. 1 Total moisture content of different sampling sites

The TMC% was found to be in the range of $1.48 \pm 0.94\%$ (lowest) to $23.03 \pm 1.25\%$ (highest). Soil sample from BH-S3 had very little moisture content i.e., $1.48\% \pm 0.94$. Seven of the soil samples had moisture content below 10%, while in most samples, moisture content was found to be within 20%. Sample from five sites had their TMC% over 20%.

Soil bulk density was another characteristic investigated. It is a measure of how thick or

firmly packed the soil is. The composition of the soil, the structure of the soil ped, the distribution of sand, silt, and clay particles, the volume of pore space, and how densely the particles are packed all influence soil bulk density. Bulk density indicates how easily roots can develop and water can filter through a profile's multiple soil strata (The Globe Program). The soil bulk density of different sampling sites is illustrated in Fig. 2

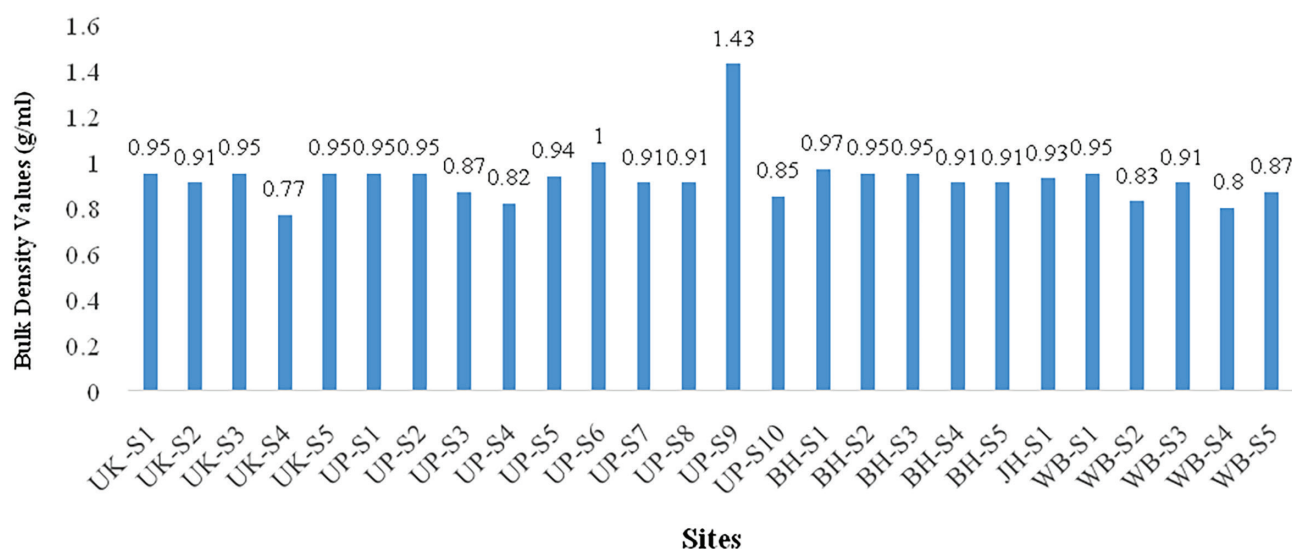


Fig. 2 Soil bulk density of different sampling sites

From the above data it was deduced that soil bulk density ranged from 0.77 g/ml to 1.43 g/ml. Soil bulk density of UP-S9 was highest i.e. 1.43 g/ml but that of UK-S4 was lowest i.e. 0.77 g/ml. Six of the sites had their bulk density below 0.90 g/ml while the remaining sites had their bulk density values above 0.90 g/ml.

The pH of soil is an important physical attribute that determines species richness

and density (Gough et al., 2000). This happens as soil pH determines the amount of nutrients that are soluble in soil water and their availability to plants. Some nutrients are more available under acidic conditions while some are available under alkaline condition. However, extreme condition of acidity or alkalinity are harmful for the soil as well as plant growth. The pH of the different sampling sites is shown in Fig. 3

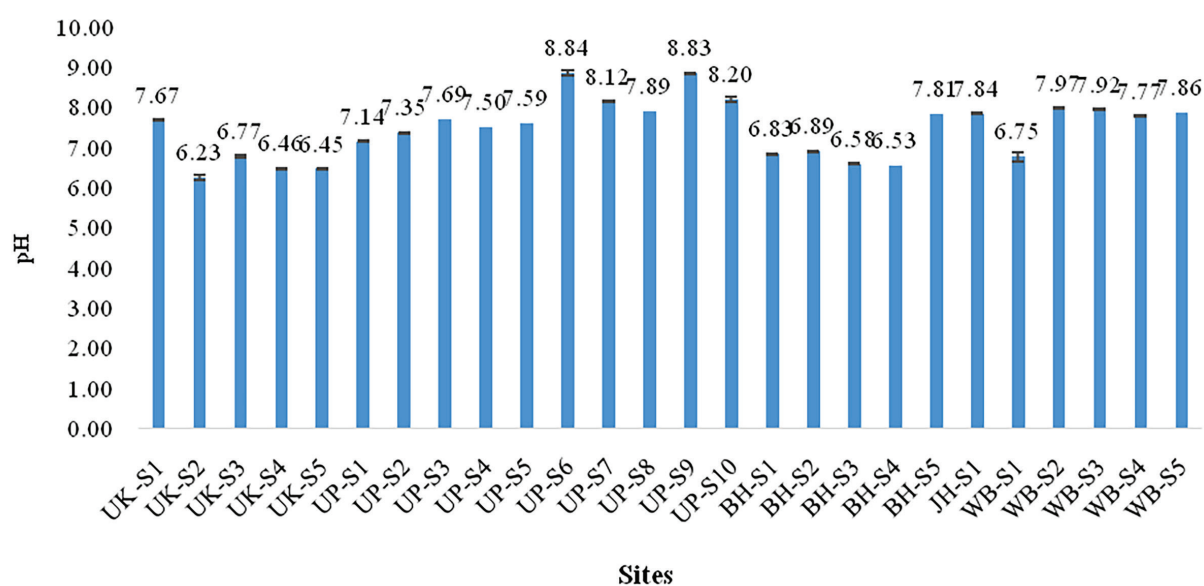


Fig. 3 Soil pH of different sampling sites

The pH of the sample sites ranged from as low as 6.23 ± 0.06 to as high as 8.84 ± 0.01 . Soil samples from UK-S2, UK-S4 and UK-S5 were found to be acidic, with pH levels lower than 6.5. The pH of 9 sites was neutral, whereas the pH of the remaining sites was alkaline.

The next parameter studied, was electrical conductivity of the soil. Soil electrical conductivity is an indicator of soil salinity, clay

content and the nutrient concentration in the field (Heiniger et al., 2003). As shown above, electrical conductivity may be categorized in different divisions and that may be used to determine the salinity of the soil so that which crop could be sown may be decided. The electrical conductivity of soils from different sampling sites was determined and is represented in Fig. 4.

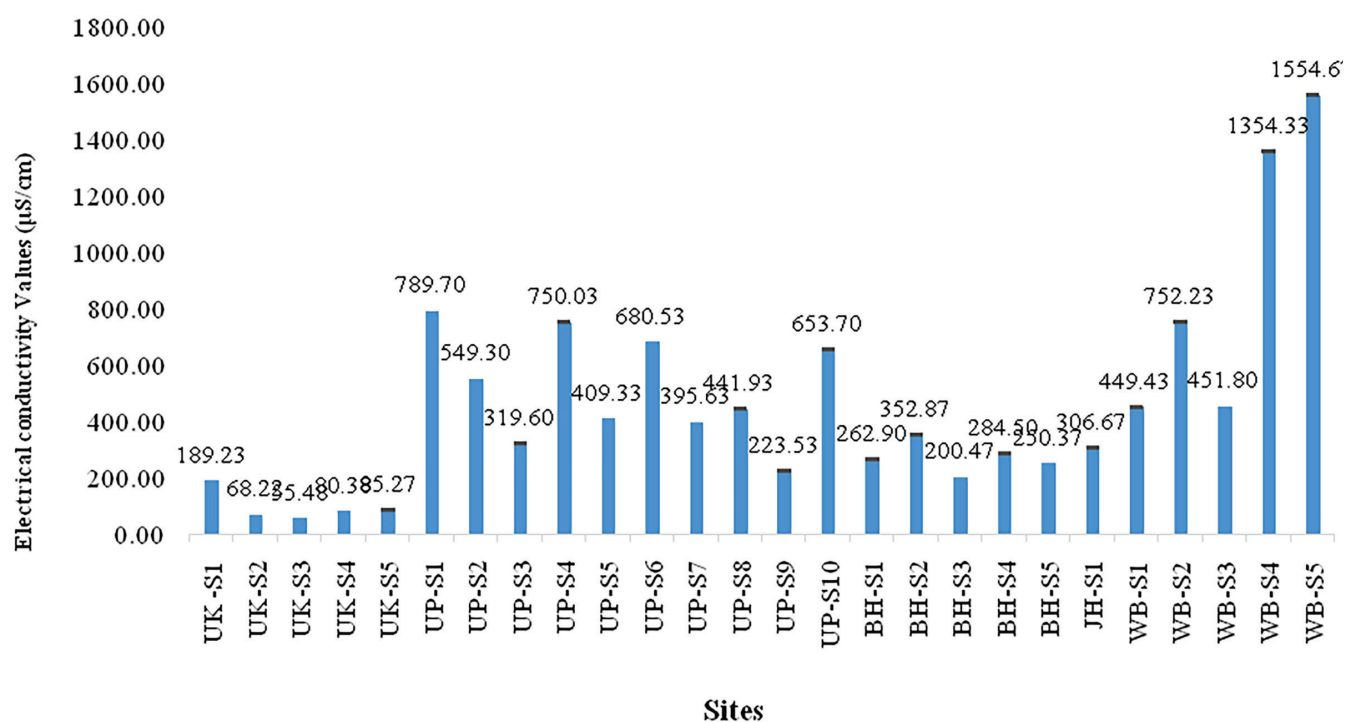


Fig. 4 Soil electrical conductivity at different sampling sites

The electrical conductivity of almost all the soil samples were within the prescribed limits of having EC below $800 \mu\text{S}/\text{cm}$. Soil samples from WB-S4 and WB-S5 showed the highest electrical conductivity value of $1354.33 \pm 2.52 \mu\text{S}/\text{cm}$ and $1554.67 \pm 2.52 \mu\text{S}/\text{cm}$ respectively. Thus, it may be said that the soil electrical conductivity was within the range at remaining all sampling sites and hence favourable for plant growth.

Soil organic carbon is a measure of the organic content present in soils. It is an important determinant of the hydraulic properties of soil like porosity, water retention and hydraulic conductivity. Thus overall, it is an important parameter determining food content in soil for uptake by plants (Allison, 1965; Rawls et al., 2004). The organic carbon content as measured for the 26 soil samples is shown in Fig. 5.

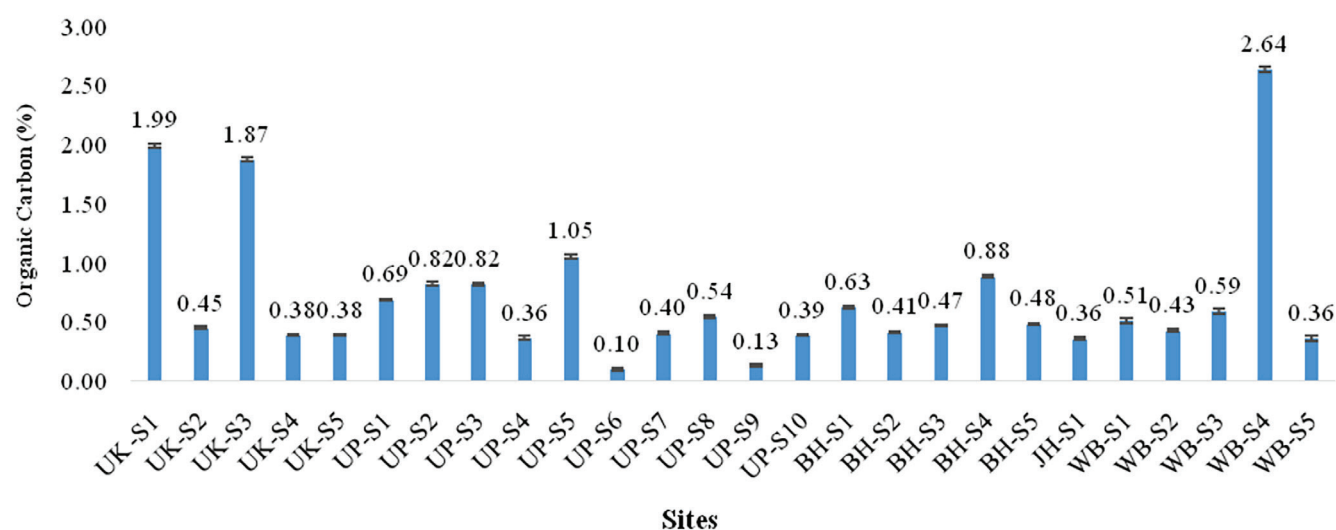


Fig. 5 Soil organic carbon content at different sites

According to the data, the organic carbon content of soil ranged from $0.10 \pm 0.01\%$ to $2.64 \pm 0.03\%$. UP-S6, which had the highest pH value of 8.84 ± 0.01 had the lowest organic carbon content of $0.10 \pm 0.01\%$. The highest quantity of organic carbon content was discovered in WB-S4 ($2.64 \pm 0.03\%$), which had an alkaline pH (7.77 ± 0.02). Soil samples from 8 different sites showed low organic carbon concentration, whereas soil samples from 11 different sites had medium organic carbon content. A total of 7 sites had high levels of organic carbon.

The next soil parameter studied was available nitrogen content. Nitrogen is the most important plant macronutrient, and its proper availability is a crucial determinant for plant growth and its optimal health. Researchers (Baričević and Zupančič, 2002) showed that increasing concentration of N added to soil resulted in increased concentration of alkaloids which is a critical component in extracts of medicinal plants. The available nitrogen content in soils from the different sites is shown in Fig. 6.

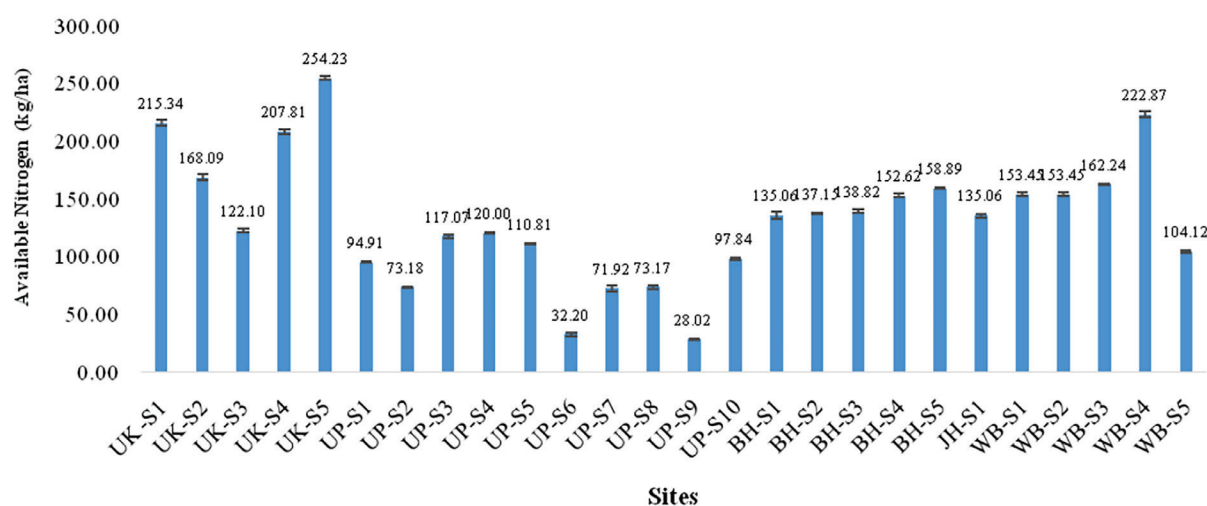


Fig. 6 Soil available nitrogen content at different sites

From the available data, it was observed that site UK-S5 had the maximum available nitrogen content (254.23 ± 1.45 kg/ha) and as per soil categories the content was low. For all the other types of soil, the available nitrogen content was low. This could be because all these samples were randomly picked from different sites, which necessarily did not receive any fertilization.

The next parameter tested was that of phosphorous which is another important

plant macronutrient. Phosphorous is a macronutrient that controls the water use efficiency, winter hardiness and promotes root formation (Chakraborty and Prasad, 2021). In case of medicinal plants enough phosphorous in soils promotes development of leaf biomass which is the main part of the medicinal plant in most cases (Stewart, 2003). The concentration of available phosphorous in soils from the different sites is shown in Fig. 7

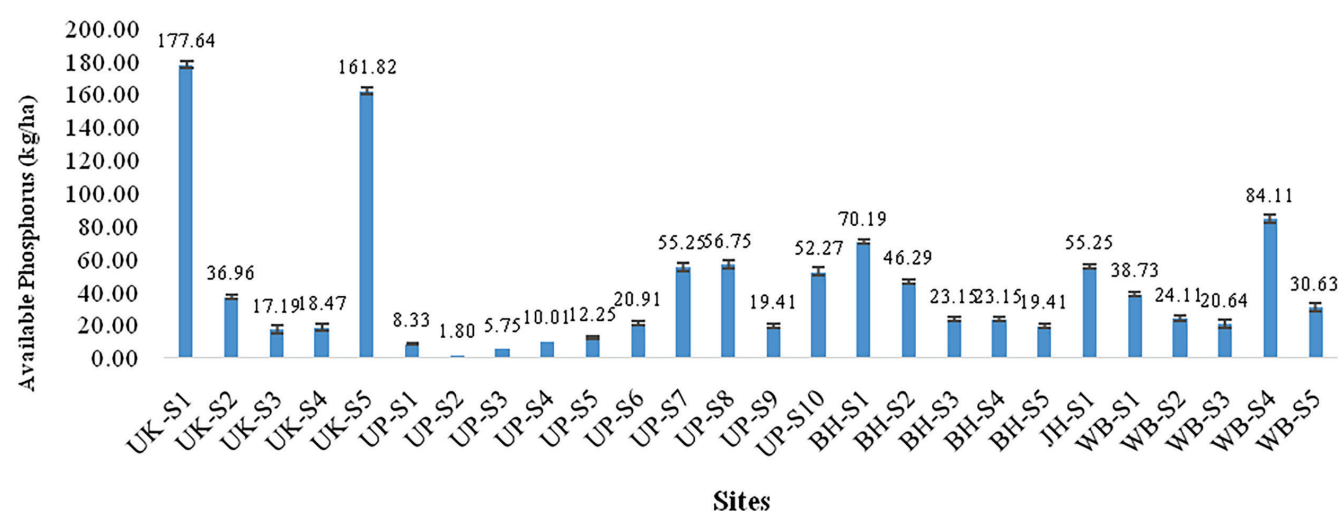


Fig. 7 Soil available phosphorus content at different sites

As per the data obtained and divisions demarcating phosphorous content in soil, the maximum P was recorded in site UK-S1 (177.64 ± 1.83 kg/ha) while a very less amount was recorded in site UP-S2 (1.80 ± 0.06 kg/ha). The remaining sites have enough amount of the P in soil. Four of the sites had available phosphorus content in low range, while 6 sites were having available phosphorus in medium range. Similarly, 4 sites had their range in high

category and the remaining sites had available phosphorus in very high category.

The next parameter is the third major macronutrient for plants, potassium. In general, potassium plays a critical role in the closing and opening of stomata and thus regulates the uptake of water by plants. It also regulates plant growth and yield (Perrenoud, 1977). Literature also suggests that proper potassium content in soil results in higher

concentration of essential oils in medicinal plants. Thus, such plants when grown in properly fertilized soil will result in good

quality of medicinal plants for maximum benefit of consumers. The potassium content of the different soil samples is shown in Fig. 8

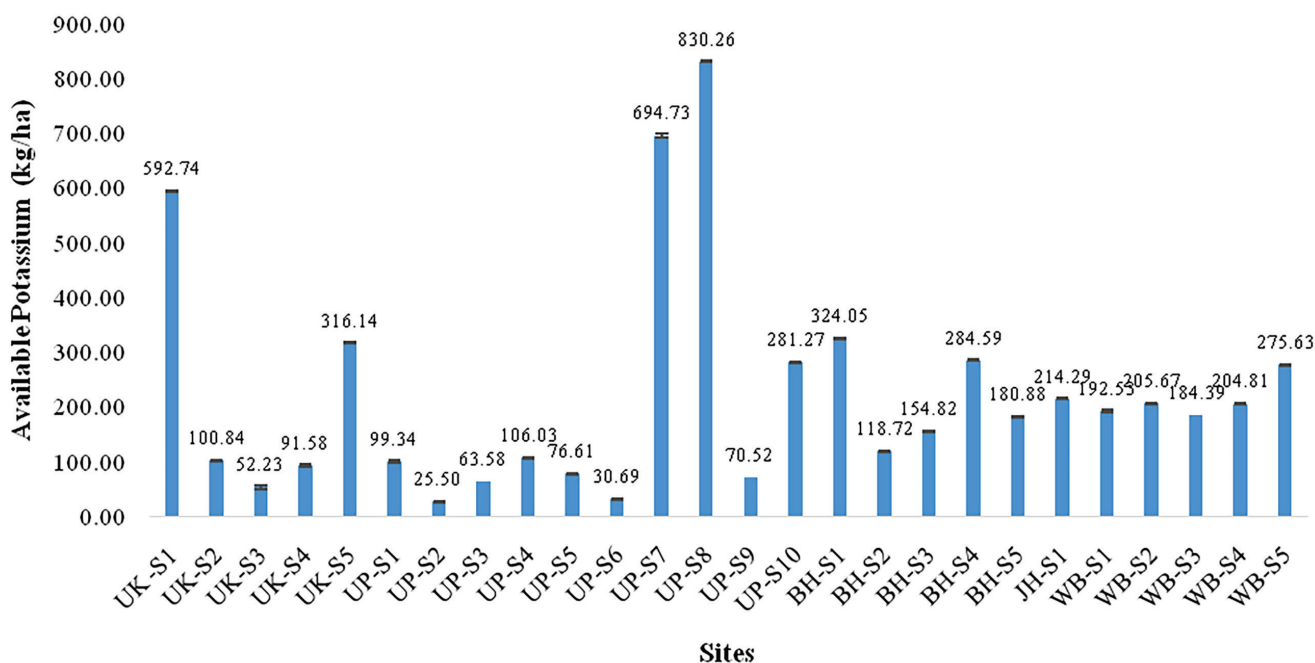


Fig. 8 Soil available potassium content at different sites

From the obtained results, it was seen that site UK-S1, UP-S7 and UP-S8 had high potassium content. As per the divisions of potassium content in soil, the potassium content was medium at twelve sites. The remaining sites had low potassium content.

Sulphur content in soil plays a role as it is up taken by plants for the formation of sulphur containing amino acids and hence the buildup of proteins, chlorophyll, and oils (Tabatabai, 1984). The sulphur content in the soil is shown in Fig. 9

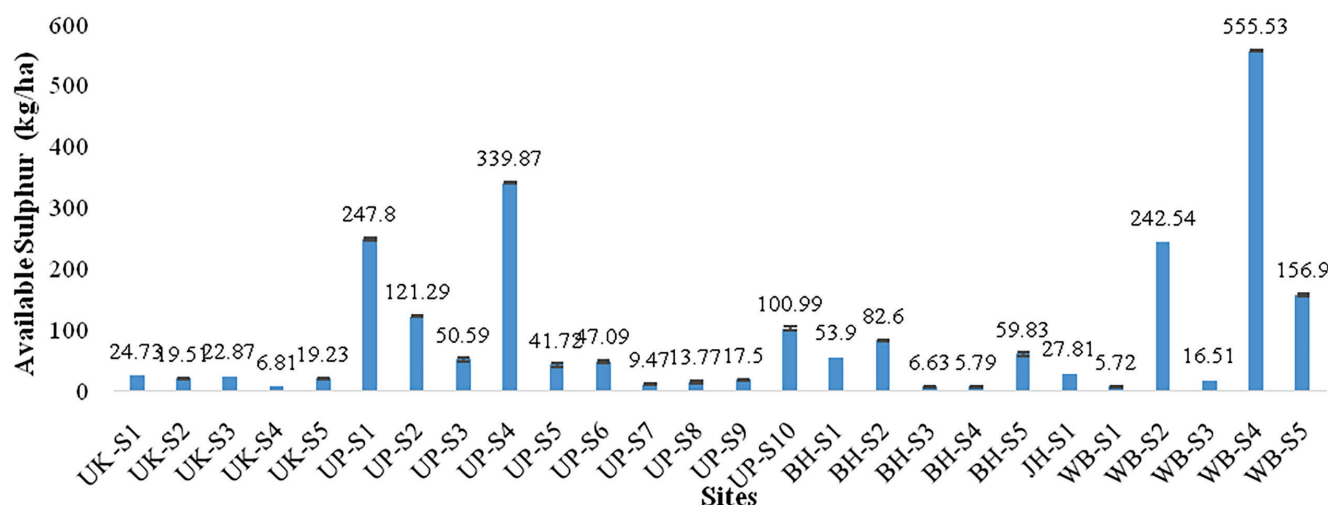


Fig. 9 Soil available sulphur content at different sites

For the results obtained for the sulphur content, it was found that 10 sites were sulphur deficient. The remaining sites had enough sulphur in their soil. Further, correlation studies will help us to understand the effect of pH, EC, or even microbial parameters on sulphur content and vice versa. Additionally, the impact of both high and low sulphur on the composition of phytochemicals can be examined.

Fig. 10 a-g shows the different heavy metals content in all the sampling sites. The concentration of 7 heavy metals Cr, Ni, As, Sr, Cd, Hg and Pb were determined using ICP-MS. Their concentration further talks about the level of pollution and contamination in the soil sampling sites.

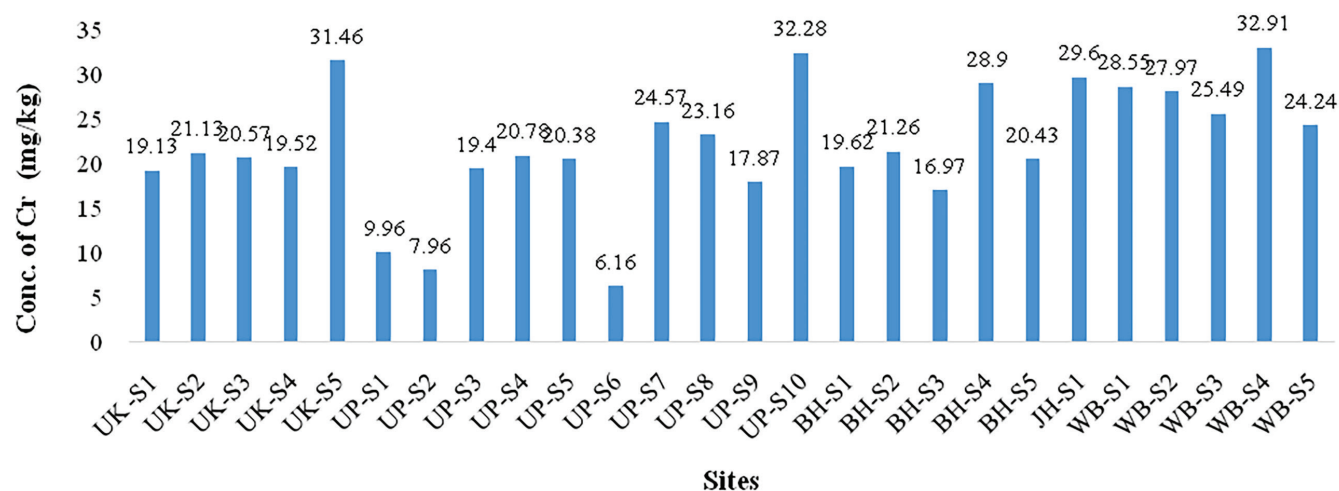


Fig. 10a Concentration of chromium at different sites

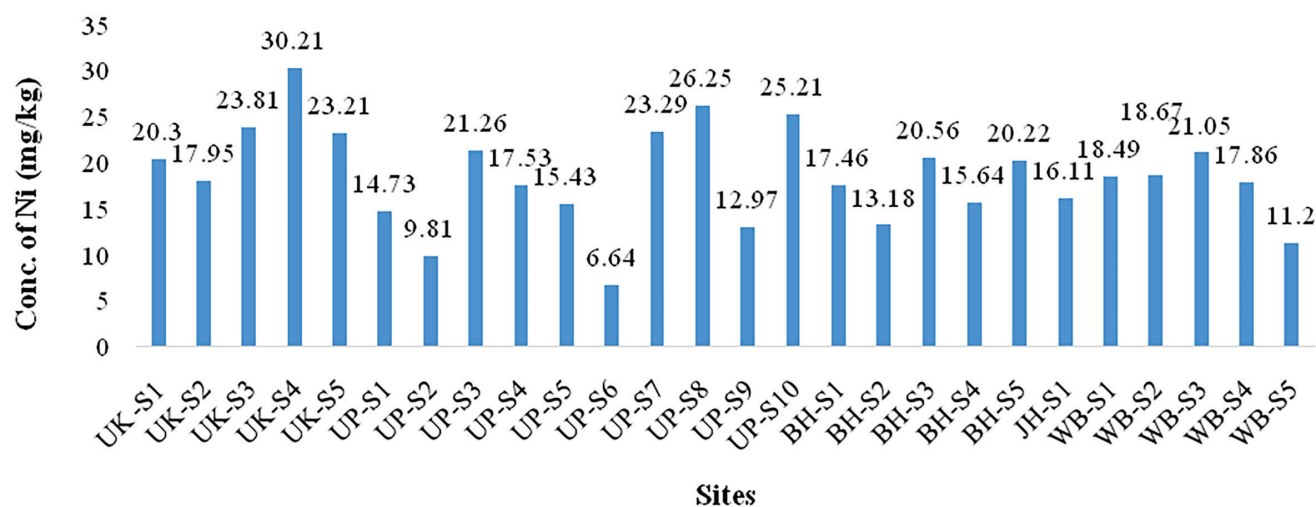


Fig. 10b Concentration of nickel at different sites

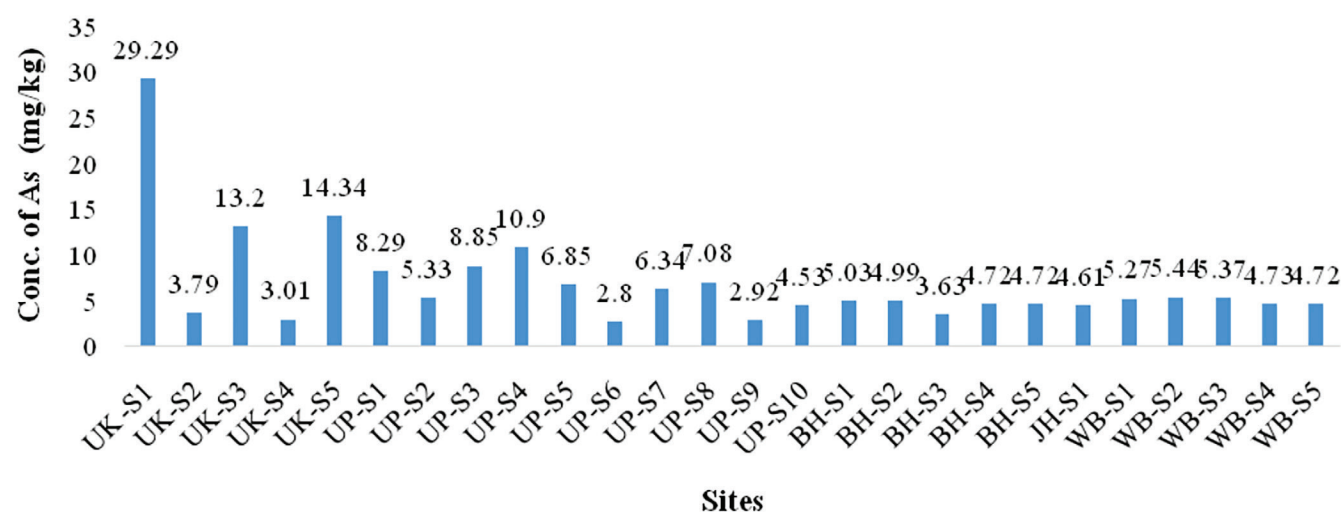


Fig. 10c Concentration of arsenic at different sites



Fig. 10d Concentration of strontium at different sites

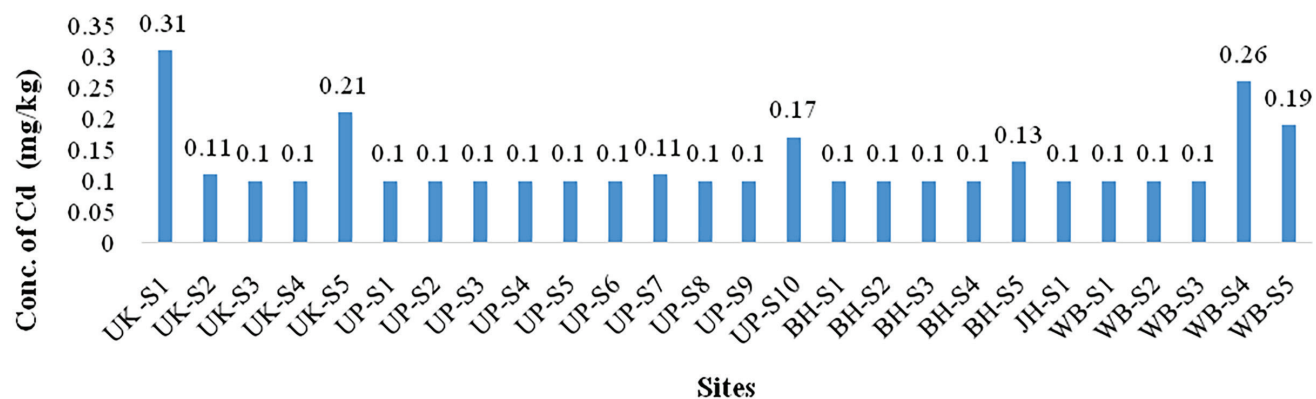


Fig. 10e Concentration of cadmium at different sites

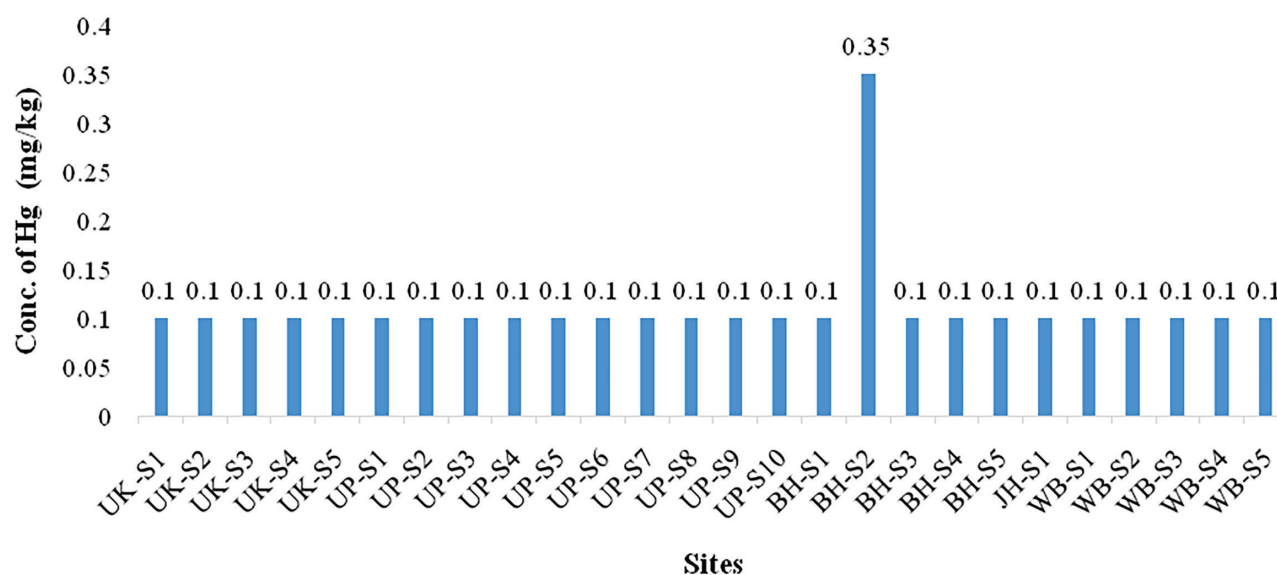


Fig. 10f Concentration of mercury at different sites

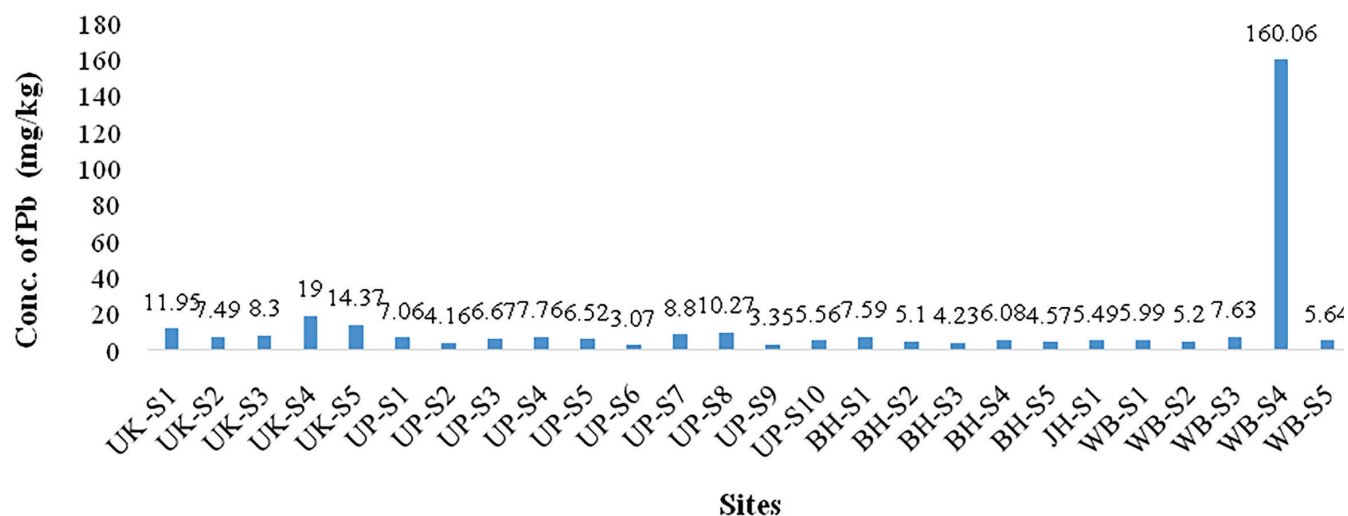


Fig. 10g Concentration of lead at different sites

Micronutrients are elements which are required by plants in very small quantities. They mainly act as co-factor of enzymes. When available to plants in the right quantity, they help in proper metabolism and bring about optimal plant growth and yield. The

concentration of the four micronutrients Zn, Fe, Mn and Cu were determined using Atomic Absorption Spectrophotometer. The values obtained for all the sites are represented in Fig. 11 a, b, c and d.

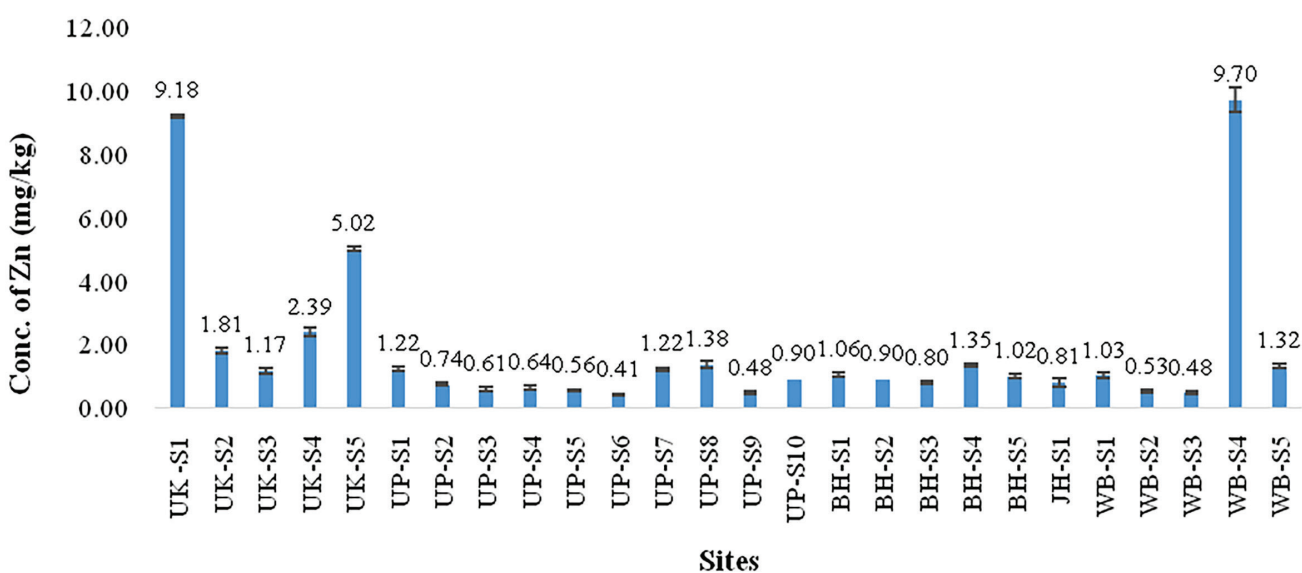


Fig. 11a Concentration of zinc at different sites

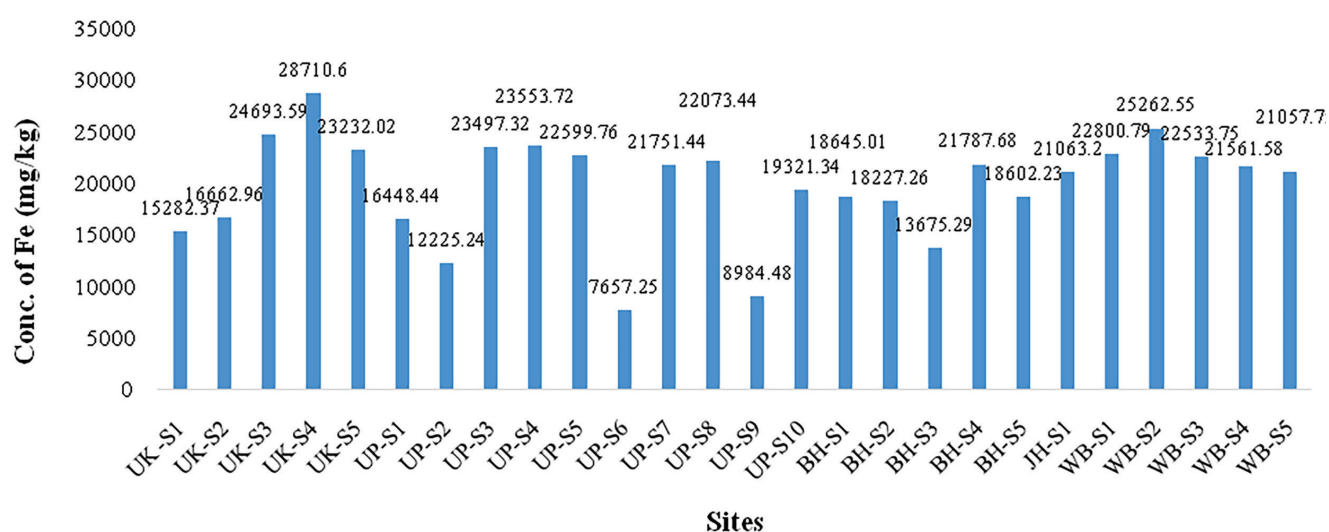


Fig. 11b Concentration of iron at different sites

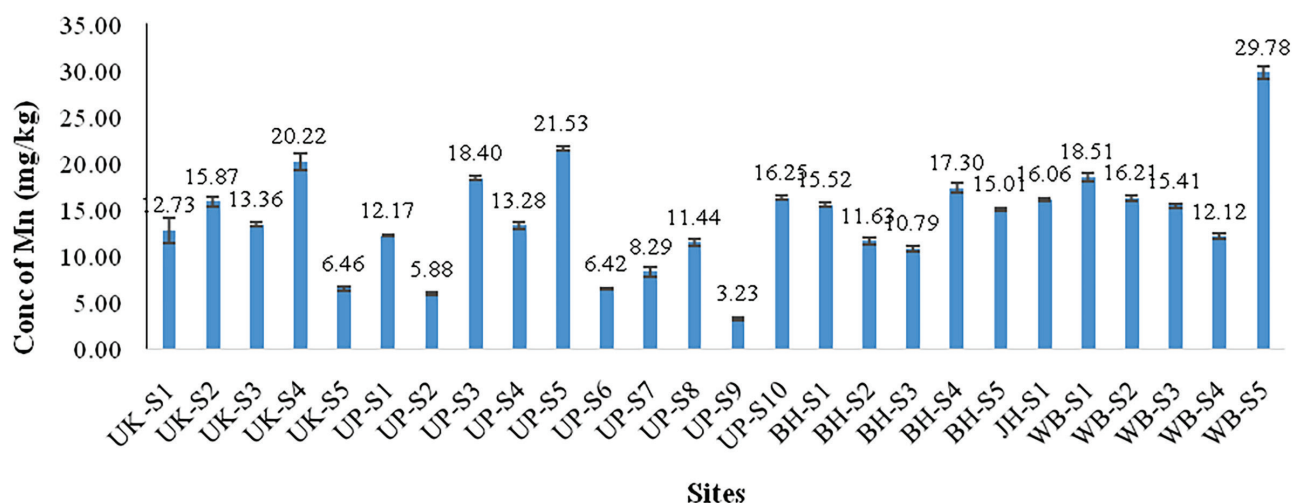


Fig. 11c Concentration of manganese at different sites

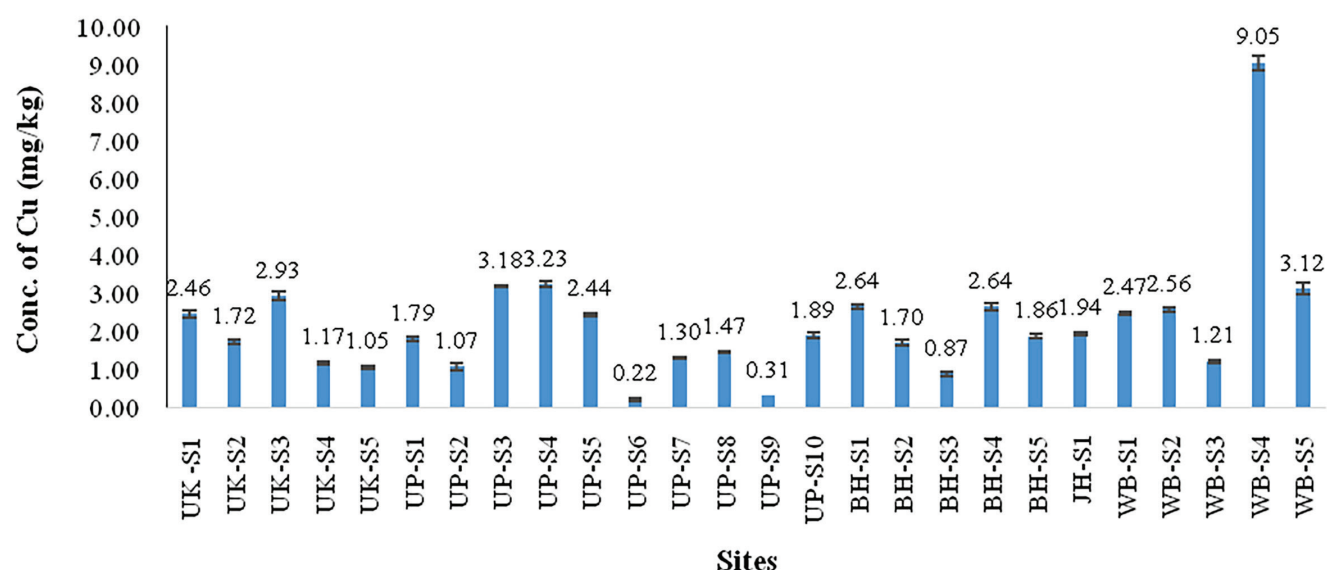


Fig. 11d Concentration of copper at different sites

As per the requirement of micronutrients by plants, there are different prescribed limits. The minimum amount of a particular micronutrient to be present in the soil is considered as the threshold. Deficient soils are those with concentrations below them, whereas sufficient soils have concentrations above them.

Though micronutrients are required by plants in very small quantities, they are important for proper metabolic functioning. Soils where micronutrients are present in insufficient quantities will result in plant having inadequate metabolism and hence, less of phytochemical content too. Thus,

cultivation of medicinal plants must be done in soils with proper nutritional content (Katyal et al., 1991).

Total and Differential Bacterial Count from Rhizosphere

Rhizosphere microbial testing involves analysing the microbial communities in the soil, rhizosphere, and roots of plants. The rhizosphere microbial test is performed in different media to calculate the bacterial count for the *Ricinus communis* L. in different locations shown in Fig. 12

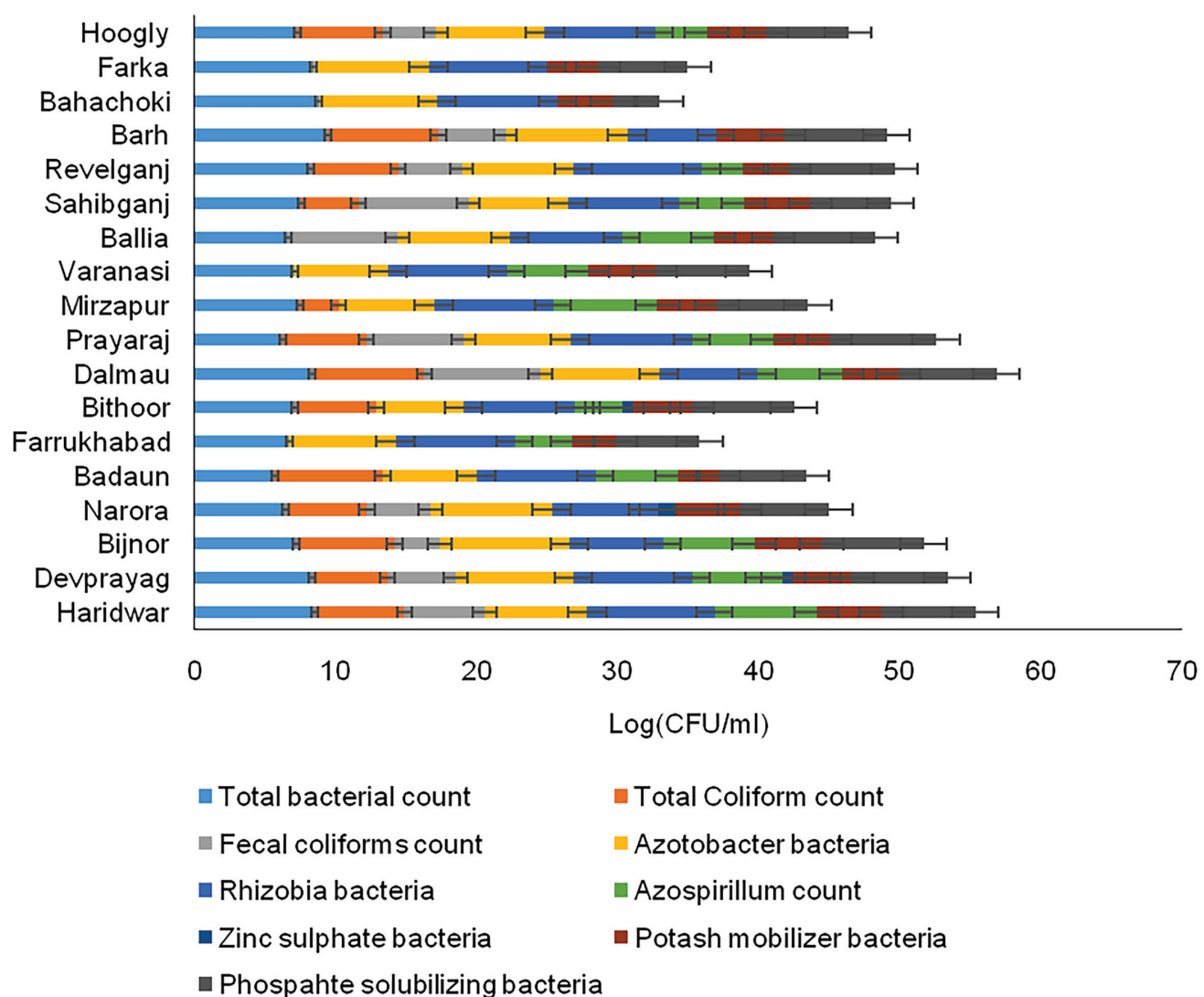


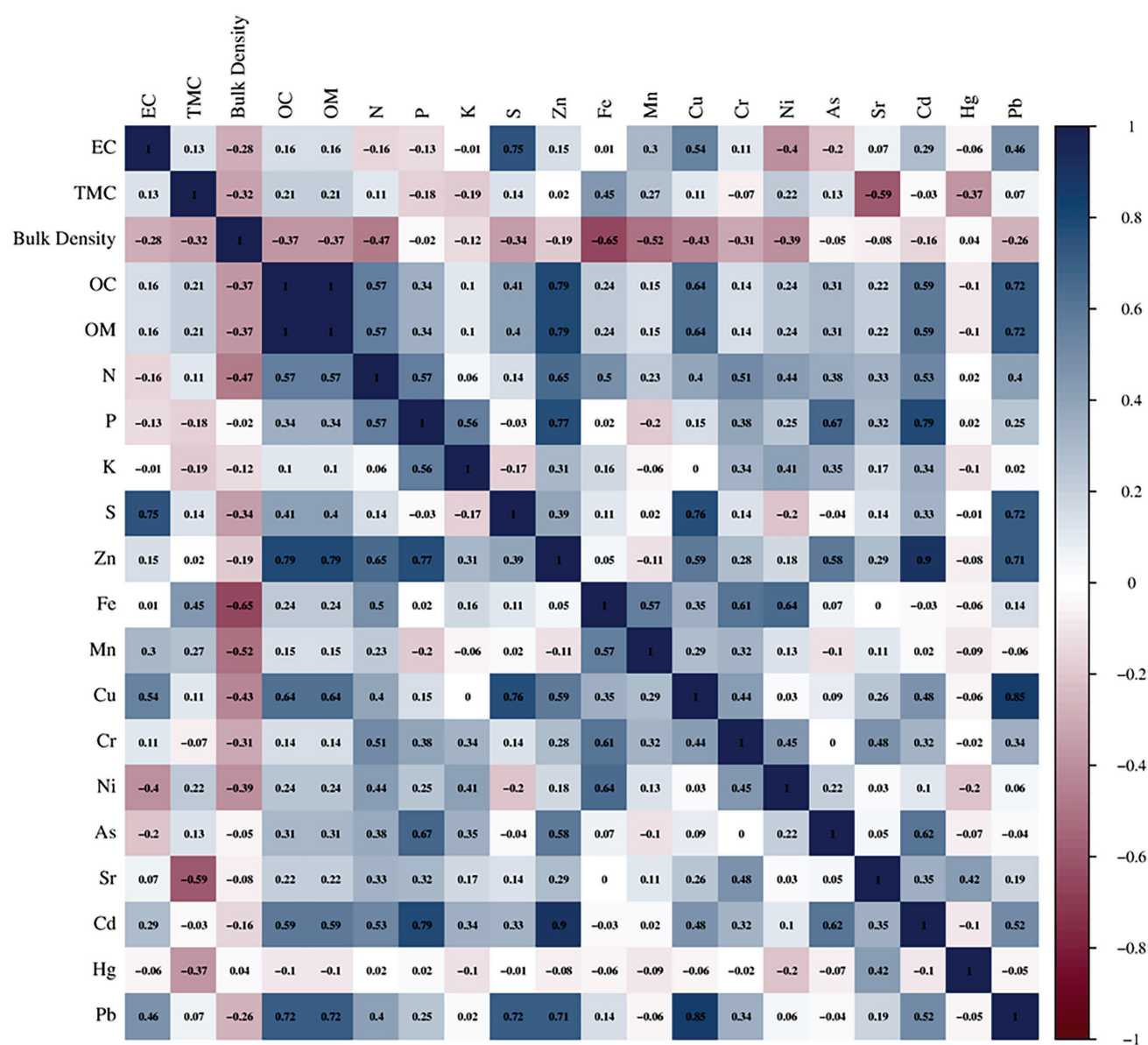
Fig. 12 Total and differential bacterial count

The total rhizosphere microbial test is performed for the identification of total bacterial count which is found highest in Barh is 9.4227 cfu/ml and lowest in Badaun is 5.6763 cfu/ml. Whereas the total faecal and

coliform count is highest in Dalmau and Barh is 7.87202 and 6.9064 cfu/ml. The results of correlation studies have been represented as a matrix in Table 4.

Correlation Coefficient Matrix

Table 4 Correlation coefficient matrix



The correlation matrix in Table 6 clearly shows the micronutrient status at different sites and according to the correlation coefficient values of one parameter against the other, the values have been colour coded. The colour coding key also shown above shows the colour codes as per the range of

the correlation coefficient value. According to correlation coefficient values of each parameter against the other, few observations can be made. These are relevant for every parameter from every site because the values were determined using information gathered for every site for every parameter.

- pH showed weak negative correlation with total moisture content, potassium, sulphur, and lead while it showed moderate positive correlation with electrical conductivity.
- A high degree of strong positive correlation between electrical conductivity and sulphur was observed, while moderate positive correlation was seen between the former and copper and lead.
- Total moisture content showed moderate positive correlation with iron; furthermore, bulk density showed weak negative correlation with mercury.
- Organic carbon showed negative correlation with mercury, moderate positive correlation with nitrogen, phosphorus, sulphur and cadmium and strong positive correlation with zinc, copper, and lead.
- Nitrogen showed a very strong positive correlation with zinc. Phosphorus showed the same with zinc, arsenic, and cadmium.
- Potassium had moderate positive correlation with zinc, chromium, nickel, arsenic, and cadmium.
- A strong positive correlation was seen between sulphur, copper, and cadmium. The same was also observed between zinc, cadmium, and lead. Iron, chromium, and nickel. Manganese and chromium shared moderate positive correlation between each other.
- Strong positive correlation was seen between copper and lead. Chromium, arsenic, and mercury had negative correlation amongst themselves. The same was also observed between nickel and mercury. A strong positive correlation was seen between arsenic and cadmium.
- Strontium showed moderate positive correlation between cadmium and mercury. The same was also seen between cadmium and lead. Mercury on the other hand showed negative correlation with lead.

Conclusion

From the physicochemical and microbial analysis of soil it was found that the parameters were different at each site. If the soil of each site is characterized as per the availability of nutrients and bacteria

according to the recommendations, then the best soil as per the area can be determined. The Table 5 shows the conclusive results of all the results obtained for different parameters from all the sites.

Table 5 Conclusive results for different parameters from all sites

Sites	pH	EC	OC	N	P	K	S	Zn	Fe	Mn	Cu	Cr	Ni	As	Sr	Cd	Hg	Pb
UK -S1	AB	WR	AR	BR	Very AR	AR	WR	WR	WR	WR	WR	WR	WR	AB	WR	WR	WR	WR
UK-S2	BR	WR	WR	BR	AR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UK-S3	WR	WR	BR	BR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UK-S4	BR	WR	AR	BR	WR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UK-S5	BR	WR	BR	BR	Very AR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S1	WR	WR	WR	BR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S2	WR	WR	AR	BR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S3	AB	WR	AR	BR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S4	WR	WR	BR	BR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S5	AB	WR	AR	BR	BR	BR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S6	AB	WR	BR	BR	WR	BR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S7	AB	WR	WR	BR	Very AR	AR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S8	AB	WR	WR	BR	Very AR	AR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S9	AB	WR	BR	BR	WR	BR	BR	BR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR
UP-S10	AB	WR	BR	BR	Very AR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
BH-S1	WR	WR	WR	BR	Very AR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
BH-S2	WR	WR	WR	BR	AR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	AB	WR
BH-S3	WR	WR	WR	BR	AR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR

Sites	pH	EC	OC	N	P	K	S	Zn	Fe	Mn	Cu	Cr	Ni	As	Sr	Cd	Hg	Pb
BH-S4	WR	WR	AR	BR	AR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
BH-S5	AB	WR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
JH-S1	AB	WR	BR	BR	Very AR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
WB-S1	WR	WR	WR	BR	AR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
WB-S2	AB	WR	WR	BR	AR	WR	WR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
WB-S3	AB	WR	WR	BR	WR	WR	BR	BR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
WB-S4	AB	CSSC	AR	BR	Very AR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR
WB-S5	AB	CSSC	BR	BR	AR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR	WR

The given parameter range is expressed in CSSC (Critical for Salt-Sensitive Crops): This range is vital for salt-sensitive crops. WR (Within Range): The parameter falls within the acceptable range. AR (Above Range): The parameter exceeds the recommended range. BR (Below Range): The parameter is below the recommended range. These parameter ranges are associated with the studies conducted by the Katyal et al., 1991, Hossain et al., 2022, Bowen, 2016, Varley, 1972; Jackson, 1973, Chopra and Kanwar, 1976; Richards, 1954, Jackson, 1973; Walkley and Black, 1934, Subbaiah, 1956, Bray and Kurtz, 1945; Black, 1965, Black, 1965; Merwin and Peech, 1951; Jackson, 1973, Lisle et al., 1994 and Retka et al., 2010.

The comprehensive investigation can also provide a better understanding of how soil quality factors, environmental fluctuations, and

altitudinal variations affect the phytochemical composition of medicinal plants.

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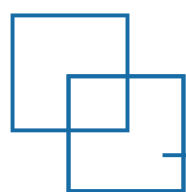
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CHAPTER
04

Traditional and Ethnomedicinal Applications



INTRODUCTION

Since the beginning of time, herbs have been a reliable source of medicine. Synthetic medications are still difficult to obtain in remote rural parts of developing nations. Many people employ readily available traditional medicinal plants to treat various diseases. Ayurveda, Siddha, Unani, and other indigenous ethnic systems use medicinal plants, and 65 to 70 percent of India's rural population rely on them for their health (Chouhan et al., 2021). Not just in India, but also globally, the use of natural medicines is becoming increasingly intriguing. The global herbal market ranged from 63.05 billion US dollars in 2014 to 71.9 billion US dollars in 2016 (Choudhury et al., 2020). Herbal components are thought to be safer and more effective than traditional chemical equivalents. However, avoiding any negative impact may not always be achievable (Kim et al., 2021). The genus *Ricinus* is monotypic, having only one species *i.e.* *Ricinus communis*. The larger, excellent green leaves and the red blooms, pods, and seeds of the red variant are like those of the African native *R. communis* var. *zanzibarensis* (Reader, 2023).

R. communis L. is a perennial shrub with softwoods that grows to a height of 1 to 5 meters. It is notable for having strong tap roots and lateral roots. The shrub's leaves are spirally organized, 1-3 cm long, green in colour, or dark green as they age, and linked stipules to a sheathing bud that is deciduous (Chouhan et al., 2021). It grows in tropical and subtropical regions of India, where it is commonly observed in the wild close to homes, along roadsides, and on waste ground that is also used for cultivation in gardens and fields. In traditional Ayurvedic medicine, it is one of the most utilized and easily accessible plants. Nearly every component of the plant-including the roots, bark, leaves, fruits, stems, seeds, and oil are utilized medicinally in a variety of formulations. Due to its many applications, this plant has commercial value. The castor plant is a member of the Euphorbiaceae family. The word *Ricinus* denotes the nature of the seeds, which resemble ticks, while *communis* represents the plant's global distribution. This shrub proliferates and has the potential to become a tree. Oil from the seeds is used for lubrication, cosmetics, biofuel, and medical purposes (Anubhav et al., 2023). This plant is widely grown throughout India, primarily in the prefectures of Madras, Bengal, and Mumbai. It is also abundant and wild in the country's



forests (Khanam et al., 2018). The castor plant has a great traditional and therapeutic significance for preserving a healthy, disease-free life. In contrast to its beneficial effects, which include those of an antioxidant, anti-histaminic, anti-nociceptive, anti-asthmatic, anti-ulcer, immunomodulatory, anti-diabetic, hepatoprotective, contraceptive anti-inflammatory, anti-microbial, central nervous system stimulant, lipolytic, wound healing, insecticidal, larvicidal, and many other medicinal properties, this plant is traditionally used as a laxative, purgative, fertilizer, and fungicide, among other traditional uses. The plant exhibits this effect because of its significant phytochemical components, which include flavonoids, saponins, glycosides, alkaloids, and steroids, among others (Jena and Gupta, 2012).

Traditional and Ayurvedic Benefits

Most remedies used in Ayurveda are derived from plants, however, they can also come from animals, metals, and minerals. The traditional Ayurvedic literature such as the Vedas, Samhitas, Nighantu, and Samgraha Granthas provide information about these medications. 'Eranda', botanically known as *R. communis* Linn, is one of the traditional herbal medicines that Ayurvedic doctors have utilized to treat a variety of illnesses (Joshi et al., 1992; Anonymous, 2000; Bhargav and Rabinarayan, 2012). Ayurvedic writings methodically documented the several forms, synonyms, parts utilized, pharmacological characteristics, activities, and indications of Eranda in the corresponding scriptures, as well as the presenting style of the herb. 'Samhitas' (treatises) and 'Samgraha granthas' (Ayurvedic compendia) both mention their usage as a component of compound preparations (Krunal and Rabinarayan, 2013). Eranda is also mentioned in the *Sayan Bhashya*, *Sankhayan Aranyaka*, and *Keshav Padhati* of the Vedic era as "*Tajadabhanga*."

Because of Eranda's qualities, which *Brihatrayi* illustrates, its uses grew throughout time. Following the development of scientific herb categorization, *Charaka* categorized Eranda under the *Bhedaniya*, *Swedopaga*, *Angamarda*, *Prashmana Mahakshaya*, and *Madhur Skanda* categories. Additionally, *Adhobhag Hara*, *Vatahara Varga* of medications, mentions it by *Sushruta*. This categorization provided a structured explanation of Eranda's karma. During the *Sangreha* (compendia) and *Nighantu* (lexicon) periods, these codes were broken. *Charaka* also mentions *Vardhmana*, *Panchangula*, and *Urubuka* in addition to Eranda. Eranda's synonyms include *Gandharvahasta*, whereas *Sushruta* includes *Kebuka* and *Chitra*. Almost every part of the plant such as fruit, stem, seeds, roots, bark, leaves, and oil are utilized medicinally in a variety of formulations (Reader, 2023). Its oil is widely used as a cathartic in the Ayurvedic, Unani, homeopathic, and allopathic medical systems (Rana et al., 2012). Various Ayurvedic preparations are mentioned here in Table 1.

Table 1 Some important preparations used against various diseases in ancient Ayurveda

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
1.	Ophthalmic disorders	Eraṇṇapallave mūle tvaci vā''jaṇ payaṇ śṇtam.....Suk-hoṇṇaṇ secane hitam. Eraṇṇadalāmūlatvak chṇtamājaṇ payo hitam. Sukhoṇṇaṇ netrayo siktaṇ vātābhiṇyandanāśanam. Taruṇamurubūkapatraṇ mūlañca vibhidya siddhamāje kṇīre. Vātābhiṇyandarujāṇ sadyo vinihanti saktupiṇṇikā coṇṇā- tender leaves and root-bark of <i>R. communis</i> (Castor-oil plant), processed with goat milk, used as an eye drop or parched flour mixed in this milk and applied lukewarm locally over the eyes, to reduce the pain, caused due to <i>Vāta</i> associated conjunctivitis and glaucoma; Eraṇṇapatramūlatvak nirmītā vātānāśinī- a potli prepared from <i>R. communis</i> (Castor-oil plant) leaves, root and bark paste, used for alleviating <i>Vāta</i> associated eye diseases; Eraṇṇapatrasaptakara-so'thavāsaindhavasanyuktaṇ. Navadṇkkopaśamanāṇ- juice of leaves, mixed with rock salt, used as an eye drop against acute eye diseases; Eraṇṇamūlaṇ saphal aprarohaṇ virjaraṇ kṇīrayutaṇ gavāṇ ca. Syād vātaraktāpaham-ugrametadāścotanaṇ sadbhiṇajo vadanti- roots, fruits and shoot pounded with cow milk, filtered well and used as an eye drop for treating <i>Vāta</i> and blood associated eye diseases; Payovimiśraṇ pa-vanodbhave hitaṇ vadanti pañcāṅgulatailameva tu- 4-16 ml castor oil along with 200 ml milk, used against <i>Vāta</i> associated cataract; Snehane cāgryamairāṇṇaṇ tu virecane- leaves of <i>Ougeinia oojeinensis</i>, <i>R. communis</i>, <i>Vitex negundo</i> and <i>Asparagus racemosus</i>, cooked in <i>Gh'taa</i>, used in treating night blindness.	Tripathi and Prasada, 2009a; Śāstrī and Chaturvedi, 2011a; Sharma, 2012a; Tripathi, 2012a; Sharma, 2012b; Tripathi, 2013a

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2.	Ear diseases	Eraṇṇapatrapuṇapākavipācitāmbu tulyādrakasya salilaṇ madhukena miśram. Paktvā ca tailalavaṇena yutaṇ sukhonṇaṇ karṇe rujaṇ harati takṇaṇameva dattam- juice extracted from leaves through <i>Purapāka</i> method, <i>Zingiber officinale</i> (Wet ginger root) juice and <i>Glycyrrhiza glabra</i> (Liquorice root) paste processed with oil, mixed with rock salt, and administered as an ear drops for quick relieve in otalgia; Eraṇṇaśigruvaruṇamūlikāpatraje rase. Caturguṇe pacettaṭṭailaṇ kṇīre cāṇaguṇānvite. Yaṇṇyāh-vakṇīrakākālī kalkayuktaṇ nihanti tat. Nāḍabādhirya śūlāni nāvanābhyāṇapūraṇaiṇ- 4 parts each of <i>R. communis</i> , <i>Moringa oleifera</i> , <i>Raphanus sativus</i> , <i>Crataeva nurvala</i> leaf juice, 8 parts of milk and 1/4 part of <i>Glycyrrhiza glabra</i> and <i>Lilium polyphyllum</i> paste used as an errhine, massage and as an ear filling for treating tinnitus, deafness, and otalgia.	Tripathi and Prasada, 2009b; Tripathi and Prasada, 2009c
3.	Thoracic diseases	Eraṇṇapatrakṇāraṇ vā vyonaṭeluguṇānvitam. Lihyādetena vidhinā surasairaṇṇapatrajam- <i>R. communis</i> leaves, <i>Kṣāra</i> or <i>Ocimum sanctum</i> leaves as well as <i>R. communis</i> , leaves of <i>Kṛāra</i> mixed with equal quantity of <i>Trikatu</i> , oil and jaggery, useful against cough; eraṇṇamūlaṇ dvipalaṇ jale'ṇṇaguṇe pacet. Tatkvātho yāvasūkāṇhyaṇ pārsvahnṭkaphasūlahā- 50 ml of decoction of <i>R. communis</i> root, mixed	Śāstrī and Chaturvedi, 2011b; Sharma, 2012c; Tripathi, 2013b
		with 1 g <i>Yavaktāra</i> , useful in alleviating flank pain, angina and <i>Ka-pha</i> associated pain; Eraṇṇatailamathavā madyamastupayorasa- intake of <i>R. communis</i> seed oil along with alcohol, whey, or milk according to the patient's strength, beneficial for <i>doṭa</i> , <i>Sāṭmya</i> , etc.	



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4.	Abdominal diseases	Payasā māṇsarasaivā triphalārasayūṇamūtramadirābhiṇ. Doṇānubandhayogāt praśastamairāṇajaṇ tailam- intake of <i>R. communis</i> seed oil in an appropriate dose along with milk, meat soup, <i>Triphalā</i> (combination of three fruits) [<i>Emblca officinalis</i> (Indian gooseberry), <i>Terminalia chebula</i> (Black myrobalan), <i>Terminalia bellirica</i> (Bedda nut)] decoction, cow urine or medicated alcohol as Anupāna according to <i>dota</i>, useful in <i>Gulma</i>, abdominal diseases, hemorrhoids, flatulence, vaginal diseases, <i>Vāta</i> associated diseases, etc; Tathā'timuktakairāṇaśephālyamīrūjāni ca. Bhṇṇaṇaṇ ghṇṭaṇ kumbhayoneṇ patraiṇ pāne ca pūjitaṁ- in case of constipation, <i>R. communis</i> seed oil is used for inducing purgation; Vibaddhavātavarcāstu bahuśūlapravāhikaṇ. Saraktapicchastṇṇārtāṇ kṇīrasauhityamarhati. Yamakasyopari kṇīraṇ dhāroṇṇaṇ vā prayojayet. Śṇṭamairāṇamūlena bālabilvena vā punaṇ. Śṇṭamairāṇamūlena.....payāṇ. Evaṇ kṇīraprayogeṇa raktaṇ picchā ca śāmyati. Śūlaṇ pravāhikā caiva vibandhaścopaśāmyati- intake of milk processed with <i>R. communis</i> root decoction or paste, useful against constipation, colic, dysentery, and bloody diarrhea caused due to abnormal movements of Vāyu; Athavairāṇasiddhena payasā kevalena vā. Yavāgūrvitareccāsyā vātaghnairdīpanaiṇ kṇṭāṇ- milk processed with <i>R. communis</i>, used as a laxative followed with Yavāgū	Tiwari, 2007a; Bhatta, 2008; Tripathi, 2010; Śāstrī and Chaturvedi, 2011c; Tripathi, 2011a; Śāstrī and Chaturvedi, 2011d; Tripathi, 2011b; Śāstrī and Chaturvedi, 2011f; Śāstrī and Chaturvedi, 2011e; Sharma, 2012d; Sharma, 2012e; Misra and Vaisya, 2012a; Sharma, 2012f; Tripathi, 2013c

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		processed with Vātahara and Dīpana herbs should be given to the patient suffering from diarrhea (if a patient is having good digestive strength); Saṇḍjātabalakāyāgniṇi punaṇ snigdhaṇ virecayet. Payasā satrivṇṭkalkenorubūkaśṇṭena vā- in <i>Pitta</i> associated abdominal disorders, after detoxification therapy and regaining strength, milk processed with <i>R. communis</i> root decoction, used as a laxative after repeated oleation therapy; Eraṇṇatailamahara-harmāsaṇ dvau vā kevalaṇ mūtrayuktaṇ kṇīrayuktaṇ vā seveto-dakavarjī. Pāyayettailamairāṇṇaṇ samūtraṇ sapayo'pi vā- intake of <i>R. communis</i> oil along with cow urine or cow milk, regularly for 2 months as a laxation, helps in the elimination of collected fecal matter, results in purification of channels, use of water is contraindicated during this period; Kaphe vātena pitte vā tābhyāṇ vā'pyāvṇṭe 'nīle. Balinaṇ svaṇṇadhayutaṇ tailamerāṇṇajaṇ hitam- in case of abdominal diseases when <i>do'a</i> get reciprocally obstructed, use of <i>R. communis</i> oil is beneficial; Eraṇṇatailaṇ daśamūlamiśraṇ gomūtrayuktastriphalāraso vā. Nihanti vātoda-raśoṭhaśūlaṇ kvāthaṇ samūtro daśamūlajaśca- intake of <i>Daśamūla</i> (group of roots of ten medicinal herbs) decoction mixed with <i>R. communis</i>, useful in alleviating <i>Vāta</i> associated abdominal swelling and colic; Pibedairāṇṇajaṇ tailaṇ vāruṇīmaṇṇamīśritam. Tadeva tailaṇ payasā vātagulmī pibennaraṇ. Śleṇmaṇyanubalepūrvaṇḥi-taṇpittānugeparam- in <i>Kaphānuvandhī Vāta Gulma</i> (Kapha associated <i>Vāta</i> Gulma) and <i>Pittānuvandhī Vāta Gulma</i> (Pitta associated <i>Vāta</i> Gulma), intake of <i>Vārumai Maṁma</i> (Medicinal preparation) along with castor oil and milk along with castor oil is recommended; Tail-amerāṇṇajaṇ vā'pi madhukakvāthasaṇyutam. Śūlaṇ pittodbha-vaṇ hanyād gulmaṇ paittikameva	



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		ca- intake of <i>Glycyrrhiza glabra</i> (Liquorice root) decoction, mixed with <i>R. communis</i> seed oil, useful in alleviating <i>Pitta</i> associated <i>Gulma</i> and pain; Viśvamerāṇṇajaṇ mūlaṇ kvāthayitvā jalaṇ pibet. Hiṇ-gusauvarcalopetaṇ sadyaṇ śūlanivāraṇam- intake of a decoction prepared from <i>R. communis</i> root and <i>Zingiber officinale</i> (Dry ginger root) in a dose of 50-100 ml, mixed with 1 g each of <i>Ferula narthex</i> (Asafoetida) and <i>Sauvarcala</i> salt, useful in alleviating abdominal pain; Eraṇṇaphalamūlāni mūlaṇ gokṇurasya ca. Śālaparṇiṇ pṇśnipa-rṇiṇ bṛhatīṇ kaṇṇakārikām..... Vātikaṇ paittikaṇ vā'pi ślaiṇmikaṇ sannipātikam. Prasahya nāsayecchūlaṇ chinnābhramiva māru-taṇ- intake of a decoction prepared from <i>R. communis</i> fruit and root, herbs of <i>Teramnus labialis</i> (Blue wiss), <i>Vigna trilobata</i> (Jungle mat bean), <i>Hygrophila auriculata</i> (Marsh barbel), <i>Laghu Pañcamūla</i>, <i>Desmodium gangeticum</i> (Sal leaved desmodium), <i>Vernonia cinerea</i> (Little ironweed) root, mixed with <i>Yavak'āra</i>, useful in quick allevia-tion of pain caused due to <i>do'as</i>; Eraṇṇamethikāguṇaniriyūho harati jaṇharaśūlāni- R. communis root, <i>Trigonella foenum-graecum</i> (Fen-ugreek) and jagger decoction, useful in quick relief of abdominal colic; Nāgarairāṇṇajaṇ kvāthaṇ kvātha iṇḍrayavasya ca. Hiṇgusau-varcalopeto vātaśūlanivāraṇaṇ- intake of 50 ml <i>Nāgarādi Kwātha</i> (Medicinal preparation) and <i>R. communis</i> root decoction, mixed with 1g each of roasted <i>Ferula narthex</i> (Asafoetida) and <i>Sauvarcala</i> salt, useful in alleviating <i>Vāta</i> associated pain.	
5.	Anorectal diseases	Vṇśārkairaṇṇabilvānāṇ patrotkvāthaisca secayet- Decoction of the leaves of <i>R. communis</i> (Castor-oil plant), <i>Adhatoda vasica</i> (Malabar nut), <i>Calotropis procera</i> (Rubber bush) and <i>Aegle marmelos</i> (Indian quince), used for sudation in hemorrhoids; Eraṇṇatailaṇ triphalārasena ca viśodhanam. Viṇpittasleṇmavātānulanomanād	Śāstrī and Chaturvedi, 2011g; Tripathi, 2012b

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		gudajāpaham. Eraṇṇatailaṇ triphalākvāthēna dviguṇēna ca. Yuk-taṇ pīṭaṇ payobhīrvā na cireṇa viricyate- <i>R. communis</i> oil mixed with <i>Triphalā</i> (combination of three fruits) juice or double quantity of <i>Triphalā</i> powder or double quantity of milk, internally used to induce detoxification of the body as well as in hemorrhoids.	
6.	Hepato-splenic diseases	Kālārtastu taruṇaṇ bhuñjīta tridinaṇ prage. Kāmalāyāṇ prāsāntyarthaṇ vaikuṇṇhaṇ pāyayennaraṇ- intake of <i>R. communis</i> and <i>Ocimum sanctum</i> (Holy Basil), mixed with water for 3 days and used against jaundice.	Tiwari, 2007b
7.	Reproductive diseases	Svinnaṇ cainaṇ yathānyāyaṇ pāyayetvirecanam. Kośāmratil-vakairaṇṇaphalatailāni vā naram. Sakṇīraṇ vā pibenmāsaṇ tailamerāṇṇasambhavam- in <i>Vāṭaja V'ddhī</i> roga, purgation given with <i>Schleichera oleosa</i> (Kusum tree), <i>Tilwaka</i> milk along with <i>R. communis</i> (Castor-oil plant) oil; Guggulurūbutailaṇ vā gomūtreṇa pibennaraṇ. Vāṭavṇḍdhiṇ nihanṭyāśu cirakālānubandhinīm. Sakṇīraṇ vā pibettailaṇ māsamerāṇṇasaṇbhavam- intake of <i>Commiphora wightii</i> (Gum guggul) along with <i>R. communis</i> oil, or milk along with <i>R. communis</i> oil, useful for 1 month in alleviating <i>Vāṭaja V'ddhī</i>; Rāsṇāyṇṇamṭairaṇṇabalāgokṇurasādhitaṇ. Kvātho'ntravṇḍdhiṇ hantyaśu rubutailena miśritaṇ. Tailamer-āṇṇajaṇ pītvā balāsiddhaṇ payonvitam. Ādhmāśūlopacitāman-travṇḍdhiṇ jayennaraṇ- intake of a decoction prepared from <i>Plu-cha lanceolata</i>, <i>G. glabra</i>, <i>Tinospora cordifolia</i>, <i>R. communis</i>, <i>Sida cordifolia</i>, and <i>Tribulus terrestris</i> (Puncture vine), mixed with 1/4th part of castor oil, or drinking of milk processed with <i>Sida cordifolia</i> and castor oil, beneficial for distension and painful hernia; Yonīsūlaharaṇ nārī yonyāṇ prakṇipya dhārayet. Picumerāṇṇabi-jaṇ tu pariṇṇhya vidhānataṇ- withholding of	Tiwari, 2007c; Tiwari, 2007d; Shar-ma, 2012g; Tripathi, 2012c; Tripa-thi, 2012d; Tripathi, 2012e



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8.	Musculo-skeletal diseases	tampon prepared from the cotton wrapped with peeled off seeds of <i>R. communis</i>, useful in vaginal pain; Eraṇṇatailena pariṭutā syāt-kārpāsapiṇṇī yadi yonimadhye. Śūlaṇ tadānīṇ śamayettadiyaṇ saṇyāvako muṇṇatikākṇto vā- cotton piece kept within the vagina soaked properly in <i>R. communis</i> oil or application of the paste prepared from <i>Sphaeranthus indicus</i> paste, cooked in castor oil, useful in vaginal pain; Eraṇṇasya ca bijāni mātuluṅgasya caiva hi. Sarpinā paripiṇṇāni pibed garbhapradāni ca- equal quantity of <i>R. communis</i> seed and <i>Citrus medica</i> seeds, pounded with <i>Gh'ṭaa</i> (Clarified butter), used internally to induce quick conception. Āmavātagajendrasya śarīravanacārīṇaṇ. Eka eva nihatyāśu eraṇṇatailakeśārī- <i>R. communis</i> oil, useful in rheumatoid arthritis; Śuṇṇhīkalkaṇ vinikṇipyā rasaireraṇṇamūlajaiṇ. Vipacet-puṇapākena tadrasaṇ kṇaudrasaṇyutaṇ. Āmavātasamudbhūtān pīṇaṇ jayati dustarām- 2 parts of <i>R. communis</i> root juice, 1-part <i>Zingiber officinale</i> paste cooked through Puṃpāka method, and extracted juice 20-25 ml mixed with honey is useful in rheumatic pain; Gandharvahasamūṇkakanaktamālāṇarūṇakapūṭikāragvad-hacitrakādīnāṇ. patrāṇyārdrāṇi lavaṇena. Sahodūkhale'vakṇudya snehaghṇe prakṇipyāvalipyā gośakṇḍbhirḍāhayet. Etat pa-tralavaṇamupadīśanti vātarogeṇu- fresh leaves of <i>R. communis</i> (Castor-oil plant), <i>Schrebera swietenoides</i> (Weaver's beam tree), <i>Pongamia pinnata</i> (Pongam oil tree), <i>Adhatoda vasica</i> (Malabar nut), <i>Holoptelea integrifolia</i> (Indian elm), <i>Cassia fistula</i> (Indian laburnum) and <i>Plumbago zeylanica</i> (Ceylon leadwort) mixed with equal quantity of rock salt, stored in an earthen pot smeared with <i>Ghee</i> (Clarified butter), cooked through Puṃpāka method. The salt obtained from this is wholesome in treating <i>Vāta</i> associated disorders;	Tiwari, 2007e; Tiwari, 2007f; Tiwari, 2007g; Tripathi and Prasada, 2009k; Tripathi and Prasada, 2009d; Tripathi and Prasada, 2009e; Tripathi and Prasada, 2009f; Tripathi and Prasada, 2009g; Tripathi and Prasada, 2009i; Tripathi and Prasada, 2009j; Śāstrī and Chaturvedi, 2011h; Tripathi, 2011e; Chaturvedi, 2011i; Tripathi, 2011c; Tripathi, 2011d; Misra and Vaisya, 2012b; Sharma, 2012h; Misra and Vaisya, 2012c; Misra and Vaisya, 2012d; Misra and Vaisya, 2012e; Misra and Vaisya, 2012f; Misra and Vaisya, 2012g; Sharma, 2012; Tripathi, 2013d; Tripathi, 2013e

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
		Eraṇṇatailayuktāṇ haritākāṇ bhakṇayennaro vidhivat. Āmānilārtti-yukto gṇdhrasivṇddhyardito niyatam- regular intake of <i>R. communis</i> (Castor-oil plant) oil mixed with <i>Terminalia chebula</i> (Myrobalan) powder in an appropriate dose, useful in rheumatoid arthritis, sciatica, hernia, and bell's palsy; Secanaṇcāmavātasya rubūkapayasā'pi vā- sprinkling with <i>R. communis</i> (Castor-oil plant) decoction, useful against rheumatoid arthritis; Kṇīrapīṇṇaṇ.....eraṇṇasya phalāni ca. Kuryācchūlanivṇṇtyarthāṇ- <i>R. communis</i> (Castor-oil plant) fruits, pounded with milk, applied externally to alleviate pain; Kṇīreṇairāṇṇatailaṇ vā prayogeṇa pibennaraṇ. Bahudoṇo virekārthaṇ jīrṇe kṇīraudanāśanaṇ- intake of 10-25 ml <i>R. communis</i> (Castor-oil plant) oil along with milk followed with the diet of cooked rice after its proper digestion, beneficial in <i>Vāta</i> associated gout; Kṇīreṇairāṇṇatailaṇca prayogeṇa pibennaraṇ. Bahudoṇo virekārthaṇ jīrṇe kṇīraudanāśanaṇ- if <i>Tridosa</i> are vitiated together in gout then purgation should be done with milk containing <i>R. communis</i> (Castor-oil plant) oil. Milk and rice should be used as a wholesome diet; Palatrayaṇ kaṇāyasya triphalāyāṇ sucūrṇitam. Saugaṇdhikapalaṇcaivaṇ kauśikasya palatrayam. Kuṇavaṇ ci-tratailasya sarvamādāya yatnataṇ. Pācayetpākavidvaidyaṇ pātre lohamaye dṇṇhe. Hanti vātaṇ tathā pittaṇ ślainmīṇaṇ khaṇjapaṇ-gutām. Śvāsaṇ sudurjayaṇ hantikāsaṇ paṇcavidhaṇ tathā- intake of <i>Siṃghanāda</i> Guggulu [prepared from 150 ml <i>Triphalā</i> (combination of three fruits) decoction, <i>Trijāta</i> Cūrma 50 g, <i>Commiphora wightii</i> (Gum guggul) 150 g and <i>R. communis</i> (Castor-oil plant) oil 200 ml cooked in an iron pan]] in a dose of 250-500 g regularly, useful in <i>Vāta</i> associated disorders, dyspnea, cough, leprosy, <i>Gulma</i>, abdominal diseases and rheumatoid arthritis; Siṇhāsapaṇcamūlachinnaru-hairāṇṇagokṇurakvāthaṇ.	



S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
		Eraṇṇatailarāmasaiṇdhavacūrṇānṇvitaṇ pīṭaṇ. Śamayati vātaraktaṇ tathā mavātaṇ kaṇṣūlaṇ. Mūtrapurīṇavibandhabradhna vikāraṇ sudurvāram- decoction of <i>Adhatoda vasica</i> (Malabar nut) root, <i>Tinospora cordifolia</i> (Tinospora), <i>R. communis</i> (Castor-oil plant) root, Pañcamūla and <i>Tribulus terrestris</i> (Caltrop) root, mixed with castor oil, <i>Ferula narthex</i> (Asafoetida) and rock salt, taken internally for rheumatoid arthritis, lumbago, obstructed urine and feces and any other such complicated diseases; Vātāsramugraṇ rūbutailamiśrā śuṇṇhāmavātaṇ śamayeduṇṇī- regular intake of <i>R. communis</i> (Castor-oil plant) oil along with <i>Tinospora cordifolia</i> (Tinospora), useful in gout; lepamerāṇṇasya phalāni vā.Kuryācchūlanivṇṇṇty- arthaṇ śtāhvāvā'nile'dhike- external application of <i>R. communis</i> (Castor-oil plant) seed, pounded with milk, beneficial in painful gout; Tailamairāṇṇajaṇ prātargomūtreṇa pibennaraṇ. Māsame- kaṇ prayogo'yaṇ ḡḇhrasyūrugrahāpahaṇ- regular intake of <i>R. communis</i> (Castor-oil plant) oil and cow urine for one month, useful in sciatica and cardiac arrest; Daśamūlī balārāśnāḡuṇṇcīśvab- heṇajam. Pibederāṇṇatailena ḡḇhrasīkhaṇjapaṇḡuṇ- intake of a decoction prepared from <i>Daśamūla</i> (group of roots of ten medicinal herbs), <i>Pluchea lanceolata</i> (Rasna), <i>Sida cordifolia</i> (Country mallow), <i>Tinospora cordifolia</i> (Tinospora) and <i>Zingiber officinale</i> (Dry ginger root), mixed with <i>R. communis</i> (Castor-oil plant) oil, useful against sciatica, lameness, and other diseases; Pañcamūlīkaṇāyantu rūbu- tailatrivṇḇdyutam. ḡḇhrasīgulmaśūlaṇ ca pīṭaṇ sadyoniyacchati- intake of Pañcamūla Kwātha, mixed with <i>R. communis</i> (Castor-oil plant) oil and <i>Operculina turpethum</i> (Indian jalap) powder, useful in pain caused due to sciatica and <i>Gulma</i>; Gomūtrairaṇṇa tailābhyāṇ kṇṇṇā pīṭa sucūrṇitā. Dīrghakālotthitāṇ hanti ḡḇhhrasīṇ kaphavātājām- regular intake	

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
		of an equal quantity of cow urine and <i>R. communis</i> (Castor-oil plant) oil, mixed with <i>Piper longum</i> (Long pepper) powder, useful in chronic sciatica; Śuṇṇhī gandharvabījābhyāṇ piṇṇābhyāṇ pāyasaṇ pacet. Bhakṇitaṇ tatkaṇisūlaṇḡḡdhrasīṇ hantyaśa-ṇśayaṇ- intake of Pāyasa prepared from an equal quantity of <i>Zin-giber officinale</i> (Dry ginger root) and <i>R. communis</i> (Castor-oil plant) seed paste, cooked in milk, useful in sciatica; Eraṇṇamūlaṇ bilvaṇ ca bṇhaṭi kaṇṇakārikā. Kaṇāyo rucakopetaṇ pīto vaṇkṇaṇavasti-jam. ḡḡdhrasijaṇ harecchūlaṇ cirakālāṇubandhi ca- intake of a decoction prepared from an equal quantity of <i>R. communis</i> (Cas-tor-oil plant) root, fruit pulp of <i>Aegle marmelos</i> (Bengal quince), <i>Solanum indicum</i> (Indian nightshade) and <i>S. xanthocarpum</i> (Yellow berred night shade), 50 ml mixed with 1-2 g black salt, useful in groin pain, cystalgia, and chronic sciatica: Niṇkṇyairāṇṇabī-jāni piṇṇvā kṇīre vipācayet. Tatpānantu kaṇisūle ḡḡdhrasyāṇ paramaṇṇadham- intake of a paste prepared from pounded and peeled off <i>R. communis</i> (Castor-oil plant) seed, cooked in cow milk, useful in lumbago and sciatica; Daśamūli kaṇāyeṇa pibed-vā nāgarāmbhasā. Kaṇisūleṇu pātavyaṇ tailamerāṇṇasambha-vam- intake of <i>Daśamūla</i> (group of roots of ten medicinal herbs) decoction or <i>Zingiber officinale</i> (Dry ginger root) decoction, mixed with 1/4 part of <i>R. communis</i> (Castor-oil plant) oil, wholesome in treating lumbago; Tailamerāṇṇajaṇ vā'pi gomūtreṇa pibennaraṇ. Māsamekaṇ prayogo'yaṇ ḡḡdhrasyūrugrahāpahaṇ- intake of <i>R. communis</i> (Castor-oil plant) oil along with cow urine, regularly for 1 month, useful in sciatica and stiffness of thighs; Āśnāti yo naraṇ siddhāmeraṇṇaphalamisīritām. Yavāḡḡṇ ḡḡdhrasīvin-naṇ pūrvāmāpnotyasau gatim- intake of <i>R. communis</i> (Castor-oil plant) fruits or gruel processed with its fruits, useful in	

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
		sciatica and enables normal movements in the body; Viśod-hyairaññabījāni piñṇvā kñīre vipācayet. Tat pāyasaṇ kaṇṇisūle gñdhraśyāṇ paramaññadhama- intake of purified pounded seeds of <i>R. communis</i> (Castor-oil plant), cooked in milk and made into pudding-like preparation, useful against sciatica and lumbar-go; Eraññatailaṇ nirguññisvarasaṇ ca pñthak samam. Pītvā kaṇṇipradeśasthaṇ vātaṇ jītvā sukhī bhavet- intake of an equal quantity of <i>R. communis</i> (Castor-oil plant) oil and <i>Vitex negundo</i> (Five leaved-chaste trees) juice, useful in <i>Vāta dosa</i> accumulated in lumbar region; Eraññatailaṇ varcaṇsthe bastisnehāśca bhedi-naṇ- intake of <i>R. communis</i> (Castor-oil plant) oil, purgation, enema, and cathartic diet, prescribed in <i>Vāta</i> associated with fecal matter; Eraññobījapūraśca gokṇuro bñhatīdvayaṇ. Aśmamedas-tathābilva etanmūlaiṇ kñtaṇśñtaṇ. Eraññatailahingvāñhyaṇ sayavakñārasaindhavaṇ. Stanaskandhakaṇṇimeññhrahñdayot-thāṇ vyathāṇ jayet- intake of a decoction prepared from an equal quantity of <i>R. communis</i> (Castor-oil plant) root, <i>Tribulus terrestris</i> (Puncture vine) root <i>Citrus medica</i> (Citron) root, <i>Solanum indicum</i> (Indian nightshade) root and <i>S. xanthocarpum</i> (Yellow berred night shade) root, <i>Bergenia ciliata</i> (Indian rock foil yam) root and <i>Aegle marmelos</i> (Indian quince) root, <i>Ferula narthex</i> (Asafoetida), rock salt and <i>Yavaksāra</i>, useful in pain manifested in breast, lumbar and cardiac region.	

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
9.	Diseases of extremities	pāyayecca tam. Māsamerāṇṇajāṇ tailaṇ gomūtreṇa samanvitam- after oleation, sudation, and venesection procedures (Snehana, Swedana and Śīrāveda, 100 ml cow urine mixed with 1/4 part of <i>R. communis</i> (Castor-oil plant) oil, taken for 1 month followed with the wholesome diet, useful in <i>Vāta</i> associated elephantiasis; Māsamerāṇṇajāṇ tailaṇ piben mūtreṇa saṇyutam- cow urine mixed with <i>R. communis</i> (Castor-oil plant) oil, given to the patient suffering from elephantiasis after the bloodletting for up to 1 month; bhīkṇṇaṇ vātakaṇṇake. Pibederāṇṇatailaṇ vā..... Raktāvasacanaṇ kuryādabhīkṇṇaṇ vātakaṇṇake. Pibederāṇṇatailaṇ vā dahet sūcibhireva ca- blood-letting done frequently along with drinking of <i>R. communis</i> (Castor-oil plant) oil, beneficial in <i>Vāta</i> -associated disorders.	Tripathi, 2011f; Sharma, 2012i; Tripathi, 2012f
10.	Dermatological diseases	Vātāripatraṇṇtaprāntenādāya cūrṇakaṇ bahuśaṇ. Nighṇṇaste-na maṇakaṇ prasruta rudhiraṇ kṇayaṇ yāti- stem of <i>R. communis</i> (Castor-oil plant), used to rub the lime over the moles repeatedly. It induces bleeding and is useful in removing unwanted moles; Eraṇṇabhūrjapūtīkaharidrāṇṇaṇ tu vātaje. Dattaṇṇadheṇu dātavyaṇ patraṇ vaidyena jānatā- <i>R. communis</i> (Castor-oil plant) leaves, used for covering the wounds in <i>Vāta</i> associated wounds.	Tripathi, 2012g; Sharma, 2012j
11.	Psychological diseases	Urubūka.....tailamapatānakināṇpariṇekādinūpayojm- a sprinkling of <i>R. communis</i> seed oil is useful in the treatment of emprosthotonus.	Sharma, 2012k

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
12.	Generalized body dis- eases	Eraṇṇamūlotkvathitaṇ jvarāt saparikartikāt. Payo vimucyate pītvā- intake of <i>R. communis</i> root decoction, useful in treating fissure-in-anal associated with fever; Tato dāhe tu sañjāte patrair- eraṇṇasambhavaṇ. Śītalairdhāritairāṇge dāhaṇ tasyāpanoday-et- covering up the whole body with <i>R. communis</i> (Castor-oil plant) leaves, useful in burning sensation caused due to fever associated with chills; Śūtameraṇṇamūlena bālabilvena vā jvarāt. Dhāroṇṇaṇ vā payaṇ pītvā vibaddhānilavarcasaṇ. Saraktapicchātisṇṭaiṇ satṇṇsūlapravāhikāt- intake of milk processed with <i>R. communis</i> (Castor-oil plant) root, helps in the expulsion of flatus, feces, and <i>Āma</i> associated disorders, results in the alleviation of	Bhisagacharya, 1953a; Bhisagacharya, 1953b; Bhisagacharya, 1953c; Tripathi and Prasada, 2009l; Śāstrī and Chaturvedi, 2011j; Śāstrī and Chaturvedi, 2011k; Tripathi, 2011g; Misra and Vaisya, 2012h; Sharma, 2012l; Misra and Vaisya, 2012i
		fever, colic, dysentery, and other diseases; Eraṇṇasya tu patrāṇi liptabhūmau nidhāpayet. Dāhādijvarīṇo dehe tāni patrāṇi dhārayet. Tena naśyati dāho'sya jvaraścaivopaśāmyati. Dāhe śānte yadā śaityaṇ tacca yuktyā nivārayet- drinking of <i>R. communis</i> oil for 15 days or 1 month, useful in <i>Vāta</i> associated inflammation; Eraṇṇo bilvamūlaṇ ca bṛhatī kaṇṇakārikā. Karaṇ- jaśacirabilvaśca śvadaṇṇṇrā ca samāṇśikā. Lepo'yaṇ sarpiṇā yukto vātasvayathunāśanaṇ. Eṇa evaṇ yathālābhaṇ pariṇekaṇ sukhāvahaṇ- external application of a paste prepared from an equal quantity of <i>R. communis</i>, <i>Aegle marmelos</i> root, <i>Pongamia pinnata</i>, <i>Holoptelea integrifolia</i>, <i>Solanum indicum</i>, <i>S. xanthocarpum</i>, and <i>Tribulus terrestris</i> mixed with <i>Gh'ṭaa</i> (Clarified butter) and sprinkling done with the decoction, useful in alleviating <i>Vāta</i> associated inflammation; Śvadaṇṇṇrairaṇṇamūlaṇ ca bilvamūlaṇ mahauṇadham. Purāṇamūlakaṇ caiṇṇ kvāthe kṇīraṇ vipācayet. Kṇīrāvaśeṇamāhṇṭya kāle saghṇṭaśarkaram. Yathāgni	

S. No.	Diseases/ Conditions	Mode of Administration/Uses	References
		pācayedenaṇ vātaśvayathunāśanam- decoction prepared from the mature root of <i>Tribulus terrestris</i>, <i>R. communis</i>, <i>Aegle marmelos</i>, and <i>Zingiber officinale</i>, properly cooked with milk till the milk is left behind, then mixed with <i>Ghee</i> (Clarified butter) and sugar, cooked again over the fire as <i>Mimdu</i> (less cooked), <i>Madhya</i> (medium cooked) and <i>Tikimma</i> (strongly cooked) respectively. Intake of this <i>Ghee</i> (Clarified butter) is useful in alleviating <i>Vāta</i> associated inflammation; Viṇvātasauṇḇe payasā rasairvā prāgbhaktamadyādurubūkatailam- intake of <i>R. communis</i> oil along with cow milk or meat juice before the meal, useful in obstructed flatus and fecal matter caused due to inflammatory diseases; Eraṇṇatailaṇ payasā gavāṇ mūtrena vā pibet. Tenāśya doṇaśeṇa śca	
		śvayathuśca nivarttate- intake of milk or cow urine along with <i>R. communis</i> oil, useful in vitiated <i>dosha</i>'s caused due to inflammation; Yadvorubūkamūlaṇ madhudigdhaṇ sthāpyate niśāṇ sakalām. Ta-sya salilasya pānāṇḇaṇhare vṛddhiṇ śamaṇ yāti- <i>R. communis</i> root, soaked in honey regularly overnight, next day morning drinking of this juice is useful in obesity; Kṇāra vātāripatrasya hiṇḡuyuktaṇ pibennaraṇ. Medovṇḍdhivināśāya bhaktamaṇṇasamanvītam- drinking of <i>R. communis</i> leaf decoction, mixed with <i>Yavakṇmāra</i> and <i>Ferula narthex</i> (Asafoetida) followed with the diet of cooked rice, useful in obesity.	
13.	Rejuvenation and virilification	Eraṇṇamūlaṇiṇḡkvātho madhutaillasasaindhavam. Eṇa yuktaratho bastiṇ savacāpippalūphalaṇ- enema of <i>R. communis</i> root decoction, mixed with honey, oil, and rock salt along with <i>Acorus calamus</i> (Sweet flag), <i>Piper longum</i> (Long pepper) and <i>Randia spinosa</i> (Common emetic nut) powder as <i>Prakṇmepa Dravya</i>, useful in promoting rejuvenating properties.	Tripathi, 2013f



Therapeutic Potential

Medicinal plants are significant for the study of their conventional uses by confirming their pharmacological effects, and they might be natural composite sources that can act as new anti-infectious agents (Ushimaru et al., 2007; Koochak et al., 2010). Nature has bestowed onto humanity many medicinal plants, and many contemporary medications have been made from these widely recognized plants. These medications are based on the natural therapeutic properties of the plants. Around the world, medicinal plants have been utilized as valuable natural resources to cure a wide range of illnesses (Farombi, 2003). *R. communis* is a soft woody little tree that is extensively distributed throughout the world's temperate and tropical climates (Verma et al., 2011). The 'bed anjeer' (*R. communis*), also called the castor oil plant of the Euphorbiaceae family, is a tiny, soft-wooded tree that grows widely in tropical and warm-weathered regions of the world. Many communities and forest inhabitants throughout the world use different sections of the plant to treat a range of illnesses

(Ladda and Kamthane, 2014). *R. communis* has many applications that make use of all its parts, such as roots, seeds, bark, leaves, flowers, fruits, and stems (Moreira et al., 2014). It is discovered that the powdered leaves work well to ward off mosquitoes as well as aphids, rust mites, and whiteflies. In addition, it has been discovered that feeding cattle with these leaves increases the amount of milk that the cattle produce. These leaves are used to make an oil that is used to treat newborn flatulence. An infusion of leaves is used to ease stomach aches and as an ocular lubricant. As such, the leaves are administered to ladies' breasts in the form of a poultice or decoction to stimulate breastfeeding. It has been claimed that fresh leaf juice can be used as an emetic in cases of opium poisoning. According to some reports, leaves can be helpful. Seeds are the primary source of oil which is in use both as an herbal medicine and as a conventional therapy for various ailments (Rana et al., 2012) as depicted in Table 2.

Table 2 Medicinal importance along with their preparation and mode of administration of *R. communis* L.

S. No.	Parts Used	Preparations	Diseases Treated and Therapeutic Uses	References
1.	Plant	-	Heart pain, joint pain, piles, inflammation, fever, bronchitis, elephantiasis, cough, laxative, dandruff, eczema, dermatitis	Ayurvedacharya, 2001; Tewari et al., 2014; Jyotsna and Kumar, 2015; Khan et al., 2017; Patra et al., 2017
		Oil with milk	Constipation	
		Oil with Aloe vera juice	Piles	
		Oil	Aching feet, arthritis, backache, muscle aches, conjunctivitis, constipation, gallbladder pain, menstrual cramps, rheumatism, skin infection, insomnia, stomachache, colic, swollen lymph nodes, tapeworm infections, intestinal worms, weak immune system	
2.	Roots	Oil	Rheumatism, burns, wounds	Ross, 2003; Chauhan et al., 2009; Rout and Panda, 2010; Singh et al., 2012; Rana et al., 2012; Upreti et al., 2016; Das et al., 2021
		Decoction	Kidney stones, expulsion of placenta, lumbago	

S. No.	Parts Used	Preparations	Diseases Treated and Therapeutic Uses	References
		Juice	Skin diseases	
		Paste along with <i>Curcuma longa</i> rhizomes	Itch and rashes	
		Extract	Abdominal disorders	
		-	Cracked heels	
3.	Leaves	-	Internal injury, pain, swelling, arthritis, constipation, cough, cold, headache, flatulence, tumour	Ayurvedacharya et al., 2001; Ross et al., 2003; Abbasi et al., 2010; Gangwar et al., 2010; Lal et al., 2012; Rana et al., 2012; Kumar et al., 2013; Sharma et al., 2014; Tewari et al., 2017; Topwal et al., 2018; Gairola, 2022; Kant et al., 2021
		Fried in mustard oil	Wounds	
		Paste	Eczema	
		Mixed with olive oil	Chronic headache	
		Mixed with sesame oil	Rigid knees	
		Juice	Poisoning	
		Extract	Sexual diseases, emmenagogue	

S. No.	Parts Used	Preparations	Diseases Treated and Therapeutic Uses	References
		Decoction	Leprosy, bilharziasis, muscular distortion, hypolactation	
		Mixed with olive oil	Paralyzed limbs	
		Poultice	Boils, sores, wounds, swellings, skin diseases	
		Powder	Wounds, boils	
4.	Stem	Juice	Toothache	Mandal et al., 2020
5.	Seeds	Oil	Intestinal worms, constipation, eczema, heel cracks, pain killer, skin diseases	Upadhyay et al., 1998; Ayurvedacharya et al., 2001; Ross et al., 2003; Mitra and Mukherjee, 2010; Gangwar et al., 2010; Sharma et al., 2014; Das et al., 2015; Editorial Board of Chinese Pharmacopoeia, 2015; Bose et al., 2015; Kumar et al., 2017
		Boiled in milk	Chronic backache, sciatica	
		Extract	Hair growth, emmenagogue	
		Paste	Carbuncle, heel cracks, wounds	

S. No.	Parts Used	Preparations	Diseases Treated and Therapeutic Uses	References
		-	Carbuncle and subcutaneous ulcer, itch, scorpion sting, fish poison	
6.	Shoots, branches	-	Toothache	Linda, 2015
7.	Seeds, leaf, roots	-	Sores	Kala et al., 2004; Adhikari et al., 2007; Yadav et al., 2009
		Oil	Skin diseases	
8.	Seed, leaf	-	Cuts	Kala et al., 2004; Alamgeer et al., 2018
		Oil/Paste	Scabies, wounds, sores, boils, acne, leprosy, ringworm, swelling, warts, other skin diseases	
9.	Fruits	-	Joint pain	Kant et al., 2021
10.	Stem and leaves	-	Stomach disorders	Ghosh et al., 2021
11.	Aerial parts	Extract	Purgative, diuretic	Ross et al., 2003

Ethnomedicinal and Folk treatments along the Ganga Basin of India

Medicinal plants have been the subjects of man's curiosity since time immemorial (Constabel et al., 1990). India is also rich in medicinal plant diversity with all three levels of biodiversity such as species, genetic, and habitat diversity. Due to its unique geographical location and different climatic conditions, Uttarakhand Himalaya has rich biodiversity and a variety of plant species (Prakash, 2014) and also has tremendous potential for domestication of medicinal plants that can be an important option for the sustainable livelihood of the hilly people in coming future (Joshi and Joshi, 2014). Major tribal populations such as the Bhotias, Boaxas, Tharus, Jaunsaries, Shaukas, Kharvar, and Mahigiri live in the Indian Himalayan Region (IHR) and employ medicinal herbs to treat illnesses naturally (Singh et al., 2003). Apart from these, many other forest-dwelling communities and local people also possess unique knowledge of the uses of medicinal plants available in the region. Several researchers have documented ethnomedicinal plants used for treating various human health-related ailments by different indigenous communities in the sub-Himalayan region of Uttarakhand (Gaur et al., 2010; Gaur and Sharma, 2011; Sharma et al., 2011). Many plants are used ethnomedicinally in the Uttarakhand area of Haridwar to treat a variety of illnesses. They employed *R. communis* fresh leaf juice, which was beneficial for intestinal worms and night blindness.

Fruit powder mixed with water is helpful for liver disorders and piles. For constipation, 5-10 drops of seed oil with milk are used (Kumar and Dangwal, 2018). Additionally, they employed the leaves as heat therapy and to cure interior injuries (Topwal and Uniyal, 2018). The plant, along with 21 other plants, is included in the Himalaya Drug Company's "Muscle & Joint Rub," a polyherbal Ayurvedic product. It is safe and efficient for treating inflammatory musculoskeletal problems, muscle sprains, and contusions (Rajanna and Kolhapure, 2005).

Furthermore, located in the northwest of the nation, Uttar Pradesh is the fourth largest and most populous state in India. It covers a huge territory, and the state's plains differ greatly from the tall mountains to the north. The cultivation of medicinal plants has become a lucrative enterprise in several regions of Uttar Pradesh. Many farmers and landowners are now switching from cultivating seasonal crops to these plants because of the large profit margins and accessibility of institutional financing. More than 250,000 hectares are used for the cultivation of herbs in Uttar Pradesh, especially in Ghazipur, Sitapur, Kannauj, Aligarh, Sonbhadra and Mirzapur districts (Sachan et al., 2015). The inhabitants of this state used a variety of medicinal herbs to treat a wide range of illnesses. For example, they used the leaves

and fruits of *R. communis* in labour pain and childbirth (Kant and Pandey, 2021). In the rural areas of Ambedkar Nagar district, this herb has also been used to treat joint pain (Prakash, 2021). Also, its oil is utilized by the residents of Kannauj district to treat body aches and pneumonia (Verma and Yadav, 2021). Other *Vantangiya* tribes of Gorakhpur have used the roots to treat fever, ascites, and inflammation. The leaves are useful against intestinal worms, earaches, night blindness, and skin infections. Moreover, the flowers are used to treat vaginal pain during menstruation and glandular tumours (Srivastava et al., 2023).

India's other eastern state Bihar is split in half by the Ganga River. The state's climate is transitional because it is situated between subhumid Uttar Pradesh and humid West Bengal in the west. In Bihar, the Gandhak, Burhi Ganghak, Bagmati, Ghaghra, Kosi, and Kamla rivers flow in major streams. 44,912 people are living in the district, belonging to several tribal communities such as Baiga, Banjara, Bedia, Chero, Chik Baraik, Gond, Gorait, Kharia, Kharwar, Khond, Lohara, Mahli, Mal Paharia, Munda, Oraon, Santal, Sauria, Paharia, etc. In their daily lives, these tribal people and other rural residents of the area use a variety of plants and plant products for food, medicine, fibre, dye, fodder, fuel, and other uses (Singh et al., 2020). *R. communis* is a highly medicinal plant utilized by the people of Gopalganj district, Bihar. They used its oil as a purgative and to treat lumbago (Prasad and Singh, 2014). Leaf formulations in district Buxar are also applied to treat

burns, nyctalopia, strangury, and vitiated *vata* diseases, particularly rheumatoid arthritis (Singh et al., 2013). Additionally, for the treatment of kidney stones, a root decoction, 1/2 g of *sunthi* (dried and powdered *Zingiber officinale*), 1 pinch of *heeng* (*Ferula asafoetida* Linn.), and regular salt are taken twice daily for 7 days (Kumari et al., 2016).

Likewise, the Indian Union's 28th state, Jharkhand is bordered to the north by Bihar, to the east by West Bengal, to the west by Chhattisgarh, and the south by Orissa. Over 29% of Jharkhand is made up of forests, making the state a great trove of woods. The ethnic people have a unique understanding of the medicinal applications of the abundant plant life in their environments. Their primary source of treatment for many illnesses, problems, and afflictions is ethno-medicine (Minakshi and Ojha, 2002). 32 distinct tribes, including Oraon, Munda, Mahli, Baraik, Bhumij, Goriat, Karmali, Bedia, Bhuiya, Lohra, Santhal, Ho, Gond, Kharia, Korba, and numerous indigenous castes like Mahto, Gonjhu, Ghansi, Teli, etc, make up 28% of the total population (Mairh et al., 2010). This plant, also known as 'Digherendi', is used in the Latehar area of Jharkhand. To treat hydrocele, the leaves are warmed over a fire and wrapped around the scrotum. The Oraon tribal people smash 1 seed and drink it with water to remove kidney and stomach stones (Marandi and Britto, 2014). Further, the seeds are used as an anticancer drug (Jain et al., 2017). The Santals and Paharias apply a paste made from root bark and some *Curcuma longa* rhizomes twice a day to treat rashes and itching (Das, 2021).

Moreover, the Indian state of West Bengal is home to several indigenous people who practice their customs and therapies, as well as a diverse range of flora and a rich variety of medicinal plants. The traditional healthcare system is entirely reliant on herbal remedies, which are now widely acknowledged for their significance in preserving biodiversity and offering hints that could lead to new research directions. But in many interior regions, there is a dearth of knowledge on the medical applications of plants (Biswakarma et al., 2017). Since ancient times, the indigenous people and tribes of West Bengal have used

a variety of plants to treat a wide range of illnesses. For example, they cured rheumatoid arthritis and employed the leaves and oil of *R. communis* as a laxative (Banerjee, 2014). Additionally, the Santal tribe employed this plant for a variety of purposes. For example, they used root paste to treat scorpion stings, seed oil to treat stomachache, and leaf paste on the breast to reduce pain after childbirth and encourage milk (Rahaman and Karmakar, 2015). The Purulia district tribals also utilized the plant's cooked and ground seeds to treat cough (Mahato and Mahato, 2023).

Conclusion and Future Perspectives

R. communis, known as the castor plant, is a powerful and extensively used medicinal herb among thousands of others. Its anti-cancer, anti-diabetic, and anti-bacterial properties are a beacon of hope in the treatment of fatal diseases across the world. It includes chemical compounds such as ricin A, B, and C, which have anti-cancer properties; it also contains alkaloid (ricinine) and glycoside, which may be utilized in a variety of herbal formulations such as anti-inflammatory, analgesic,

antipyretic, cardiac tonic, and antiasthmatic. The presence of a wide range of bioactive phytochemicals is responsible for its diverse biological activity. Further research and use of these plant components in isolated form can be conducted to investigate their mechanism of action and decode the real method by which these plant phytochemicals reach their target and exhibit their effect. Novel medications can be developed by conducting *in vitro* and animal investigations on these phytoconstituents.

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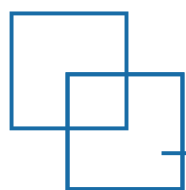
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CHAPTER
05

Phytochemical Analysis



INTRODUCTION



Ricinus communis, commonly known as the 'castor oil' plant, is a significant medicinal plant belonging to the Euphorbiaceae family. It is native to Africa and India but is distributed throughout tropical, subtropical, and temperate regions worldwide. The plant is characterized by long-petiole leaves with lobed blades and unisexual flowers arranged in panicles. Its fruit is a three-chambered capsule containing seeds that are dorsoventrally flattened and covered by grayish, silvery, or light brown seed coats. The name "*Ricinus*" means 'tick,' referring to the seed's appearance, and "*communis*" signifies 'common,' reflecting its widespread presence (Polito et al., 2019).

Phytochemical analysis of *Ricinus communis* has revealed the presence of various compounds such as flavonoids, phenolic compounds, fatty acids, amino acids, terpenoids, and phytosterols. These compounds contribute to its medicinal properties, including anti-inflammatory, antifertility, antimicrobial, antioxidant, and wound-healing activities. Traditional medicine widely uses different parts of the plant for treating various ailments like abdominal disorders, arthritis, muscle aches, rheumatism, and more. However, it is essential to note that some parts of the plant, particularly the seeds, contain toxic components like ricin, agglutinin, nudiflorin and ricinine, which can be harmful if ingested (Suurbaar et al., 2017; Franke et al., 2019).

The species has a rich history in traditional and folk medicine, with its seeds and derivatives being utilized for their therapeutic benefits. The geographical diversity of the plant, coupled with its phytochemical richness and traditional usage, underscores its significance in herbal medicine and highlights the need for further research to explore its medicinal potential and active compounds responsible for its diverse activities.



Sampling Sites

Table 1 Samples of the *Ricinus communis* were collected from various state-specific locations

S. No.	Sampling sites
1.	Bithoor, Uttar Pradesh
2.	Dalmau, Uttar Pradesh
3.	Prayagraj, Uttar Pradesh
4.	Mirzapur, Uttar Pradesh
5.	Ballia, Uttar Pradesh
6.	Revelganj, Bihar
7.	Patna, Bihar
8.	Barh, Bihar
9.	Sahibganj, Jharkhand
10.	Gaumukh, Uttarakhand
11.	Gangotri, Uttarakhand

Phytochemical Analysis

Phytochemical components like tannin (by titration), total saponins (by gravimetry), total polyphenols, and total flavonoids (by UV-visible spectrophotometer), were determined for their respective contents via in-house protocols using API standards and literature, developed in Chemical Science Division, Drug Discovery and Development Department, Patanjali Research Foundation, Haridwar. Advanced methods and techniques were employed for the identification and quantification of secondary metabolites and active components within the collected samples. High-performance thin layer chromatography (HPTLC) served to detect marker compounds and provide a chromatographic fingerprint of

the plant sample. The hyphenated techniques have been proven as a powerful tool for the identification and structural characterization of known compounds. Hence, for further identification and quantification of compounds high-performance liquid chromatography (HPLC) and ultra performance liquid chromatography quadrupole time-of-flight mass spectrometry (UPLC/MS-QToF) were employed.

Determination of Tannin Content

A 1-10 g sample was taken and mixed with 50 ml of Milli-Q water. The mixture was then

shaken and sonicated for 30 minutes before being brought up to a volume of 100 ml and filtered. From this solution, 10 ml was extracted and combined with 750 ml of Milli-Q water. Subsequently, 25 ml of indigo sulfonic acid was added, and the solution was shaken. The mixture was then titrated with 0.1N potassium permanganate solution until a golden yellow color appeared, indicating the endpoint. A blank run without the sample was also conducted.

Determination of Saponin Content

A 5 g sample was taken and combined with 50 ml of a 1:1 (methanol:water) solvent. The mixture was then refluxed for 1 hour, cooled, and filtered. This process was repeated three times. The filtrates were combined, concentrated, and evaporated to dryness. Subsequently, 25 ml of petroleum ether was added, and the solution was refluxed for 10 minutes. After cooling, the ether layer was decanted. Next, 10 ml of methanol and 100 ml of acetone were added, followed by filtration. The filter paper with residue was dried at 80°C for 1 hour and then weighed.

Determination of Total Polyphenol Content

A 1 ml sample was taken and placed in a test tube. One milliliter of Folin–Ciocâlteu reagent was added, and the mixture was incubated for 5 minutes. Following this, 1 ml of a 10% sodium carbonate solution was added. The solution was then kept in the dark for 1 hour. Absorbance was measured at 760 nm using a UV-visible spectrophotometer. The same steps were repeated for gallic acid to establish linearity.

Determination of Total Flavonoid Content

A 1 ml sample was placed in a test tube, followed by the addition of 0.4 ml of 10% aluminum chloride, 0.4 ml of sodium acetate, and 3 ml of ethanol. The mixture was then left at room temperature for 30 minutes. Subsequently, the absorbance was measured at 450 nm using a UV-Visible spectrophotometer. These steps were repeated for quercetin dihydrate to establish linearity.

HPTLC Fingerprinting

The application of HPTLC in the study reflects a prevalent methodology documented in the literature for profiling secondary metabolites. The use of HPTLC not only enables the rapid separation of compounds but also aligns with the commonly reported diverse chemical

fingerprints found in *Ricinus* species. This technique has been recognized for its effectiveness in exploring the qualitative aspects of secondary metabolites in various plant species. As per WHO Technical Report Series, No. 1010, (2018), HPTLC

chromatographic patterns, generally refer as “fingerprints”, are used for the identification of phytochemicals. The bands or spots obtained during the test are characteristic of a particular herb. A color image of a typical TLC fingerprint provides a clearer guide to the users.

Sample Preparation

About a gram of sample from each batch individually was dissolved in 10 ml of methanol. The samples were shaken and sonicated for 20 min. Next, the solution was centrifuged for 5 min at 5000 rpm, and the clear solution thus obtained was used for analysis.

Methodology and Analytical Conditions

Analysis was performed on CAMAG HPTLC (Muttenez, Switzerland), equipped with an Automatic TLC Sampler (ATS 4), TLC scanner 4 and TLC visualizer. Data processing

acquisition and visualization were achieved using win-CATS software (version 1.4.10). The chromatographic conditions for the HPTLC analysis were as follows:

Stationary phase	TLC Silica gel 60 F254 aluminum sheet (1.0554.0007)
Mobile phase	Chloroform: methanol (9:1v/v)
Saturation time	15 minutes
Migration distance	70 mm
Band length	8 mm
Injection volume	15 µl
Visualization	254 nm and 366 nm and under white light before derivatization

High-Performance Liquid Chromatography (HPLC)

Sample and Standard Preparation

Sample Preparation: About 1 g of sample from each batch individually was dissolved into 25 ml of hydromethanol (20:80). The solution was sonicated for 4 hours, centrifuged for 5 min at 9000 rpm, and filtered using a 0.45 µm nylon

filter. The filtered solution was used for analysis.

Standard preparation: Standards gallic acid, rutin, and ellagic acid were dissolved in methanol to prepare a 1000 µg/ml standard stock solution. A 0.1 ml of 1000 µg/ml from each standard stock solution was taken to make 100 µg/ml of standard mix working solution.

Analytical and Instrumentation Condition

Analysis was performed by Prominence-XR UHPLC system (Shimadzu, Japan) equipped with a Quaternary pump (NexeraXR LC-20AD XR), DAD detector (SPD-M20 A), auto-sampler (NexeraXR SIL-20AC XR), degassing unit (DGU-20A 5R) and column oven (CTO-10 AS VP). Separation was achieved using a

Shodex C18-4E (5 µm, 4.6 × 250 mm) column, subjected to binary gradient elution. The two solvents used for the analysis consisted of water with 0.1% orthophosphoric acid (solvent A) and acetonitrile (solvent B). The column temperature was kept at 30°C and flow was set at 1.0 ml/min during the analysis. Ten microliters of standard and test solution were injected. Wavelengths were set at 271 and 257 nm.

Gradient program used

Time (Min)	A%	B%
0	95	5
2	95	5
10	50	50
15	50	50
17	5	95
20	5	95
25	95	5
30	95	5

Identification of Compounds by Ultra Performance Liquid Chromatography Quadrupole Time-of-Flight Mass Spectrometry (UPLC/MS-QToF)

The objective of this analysis was to identify the major compounds in *Ricinus communis* (PRF/CHI/1223/1293) by UPLC/MS-QToF.

minutes and filtered through 0.22 µm nylon filter.

Sample Preparation

A 500 mg powdered sample was dissolved in 10 ml methanol and sonicated for 30 min. The solution was centrifuged at 10000 rpm for 5

Analytical and Instrumentation Conditions

Analysis was performed on a Xevo G2-XS QToF (Waters Corporation, USA) with Acquity UPLC- I Class and Unifi software. Separation

was carried out using Acquity UPLC HSS-T3 (100 × 2.1 mm, 1.8 µm) column with the flow rate of 0.3 ml/min using gradient elution of 0.1% v/v formic acid in water (mobile phase A) and 0.1% v/v formic acid in acetonitrile (mobile phase B). The column was maintained at 40°C throughout the analysis and sample

temperature was set at 20°C. Detection was carried out by Xevo G2-XS QToF. One microliter of sample solution was injected in UPLC/MS-QToF and chromatograms were recorded in positive and negative ionization mode for 45 min.

Gradient program

Time (min)	Flow (ml/min)	Mobile phase A%	Mobile phase B%
0	0.3	95	5
5	0.3	95	5
15	0.3	75	25
35	0.3	40	60
45	0.3	25	75
46	0.3	95	5
50	0.3	95	5

Xevo G2-XS QToF Parameters

Parameter	Polarity (+ve)	Polarity (-ve)
Ionisation type	ESI	ESI
Mode	MS ^E	MS ^E
Mass range (m/z)	50-1200 m/z	50-1200 m/z
Scan time	0.5 s	0.5 s
Cone Voltage	40 V	40 V
Capillary	1.0 kV	2.0 kV
Low CE	6.0 eV	6.0 eV
High CE	15-60 eV(ramp)	15-60 eV(ramp)
Source temperature	120°C	120°C
Desolvation Temperature	500°C	500°C
Cone gas flow	50 L/h	50 L/h

Parameter	Polarity (+ve)	Polarity (-ve)
Desolvation gas flow	900 L/h	900 L/h
Lock Spray (Leucine Enkephalin)	556.2766 m/z	554.2620 m/z
Lock mass scan time	0.5 s	0.5 s
Lock mass interval	30 s	30 s

Results and Discussion

Phytochemical Analysis

The quantitative phytochemical analysis of *R. communis* revealed significant variations in the content of tannins, saponins, total phenolics, and total flavonoids among samples collected from different locations. The results, detailed in Table 2, show that the tannin content ranged from 0.020% to 0.097% w/w, saponin content varied from 3.508% to 8.336% w/w, total polyphenol content was between 0.006% and 0.013% w/w, and total flavonoid content ranged from <0.001% to 0.002% w/w.

Tannins are known for their astringent properties and potential health benefits, including antioxidant and antimicrobial activities. The variation in tannin content among the samples suggests that environmental factors significantly influence the synthesis of these compounds. Saponins possess a range of bioactivities, including anti-inflammatory, immune-boosting, and

cholesterol-lowering effects. The observed differences in saponin content highlight the plant's adaptive responses to different environmental conditions, which could affect its bioactivity.

Polyphenols are well-documented for their antioxidant properties, contributing to the plant's protective effects against oxidative stress. The polyphenol content in *R. communis*, although relatively low, indicates its potential role in neutralizing free radicals and preventing oxidative damage. Flavonoids, with their known antioxidant, anti-inflammatory, and anti-carcinogenic properties, further enhance the therapeutic potential of the plant. The low flavonoid content observed in this study suggests that their synthesis might be highly sensitive to environmental factors. These variations highlight the influence of geographical and ecological factors on the phytochemical composition of the plant species.

Table 2 Phytochemical analysis of *Ricinus communis* collected from different locations

S. No.	Samples	Tannin content (%w/w)	Saponin content (%w/w)	Total polyphenol content (%w/w)	Total flavonoid content (%w/w)
1.	Bithoor, Uttar Pradesh	0.020	6.815	0.012	0.001
2.	Dalmau, Uttar Pradesh	0.039	5.432	0.012	0.001
3.	Prayagraj, Uttar Pradesh	0.060	5.751	0.011	0.002
4.	Mirzapur, Uttar Pradesh	0.061	3.508	0.008	<0.001
5.	Ballia, Uttar Pradesh	0.039	5.521	0.006	<0.001
6.	Revelganj, Bihar	0.080	4.588	0.010	0.001
7.	Patna, Bihar	0.039	7.529	0.011	0.001
8.	Barh, Bihar	0.040	4.666	0.009	0.001
9.	Sahibganj, Jharkhand	0.057	5.910	0.013	0.002
10.	Gaumukh, Uttarakhand	0.097	7.479	0.010	<0.001
11.	Gangotri, Uttarakhand	0.058	8.336	0.008	<0.001

Previous studies have documented the diverse bioactivities of *R. communis*, attributing them to its rich phytochemical profile. For instance, the antimicrobial activity of the plant species has been linked to its tannin and saponin content, which disrupt microbial cell membranes and inhibit microbial growth. The antioxidant properties, primarily due to polyphenols and flavonoids, support the plant's use in managing oxidative stress-related conditions. Studies also highlight the anti-inflammatory effects of *R. communis*, with saponins and flavonoids playing a crucial role in modulating inflammatory pathways.

The presence of these compounds in varying concentrations across different

samples suggests that *R. communis* from different regions may exhibit different levels of bioactivity.

HPTLC Fingerprint Analysis

The HPTLC fingerprinting of *R. communis* samples revealed distinct bands at 254 nm, 366 nm, and under white light. The banding pattern indicated the presence of various phytochemicals, with variations in intensity reflecting the concentration differences among the samples. The consistent banding patterns across different wavelengths confirm the reproducibility and reliability of HPTLC in profiling the phytochemicals of *R. communis*.

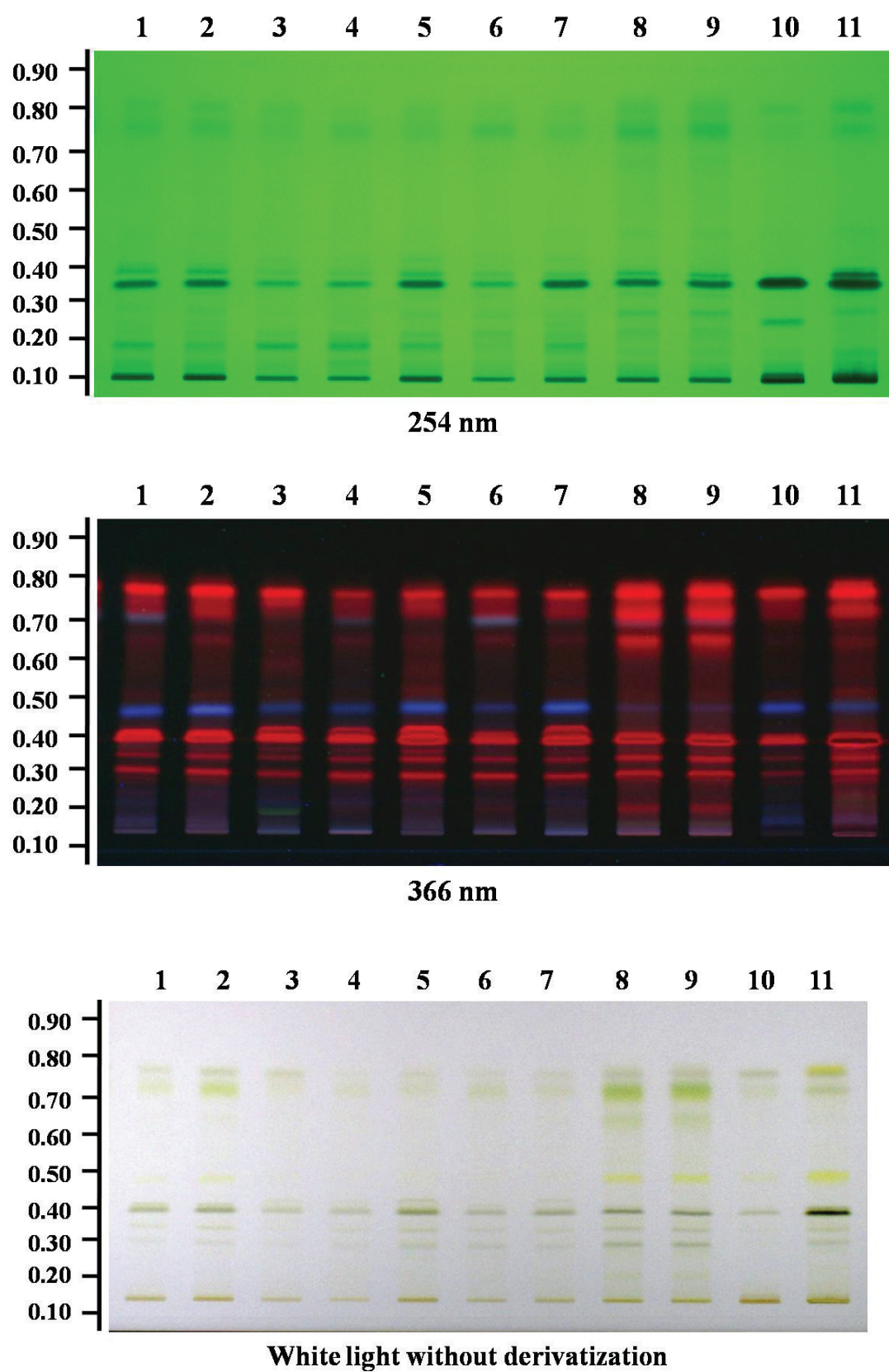


Fig. 1 HPTLC fingerprinting of methanolic extract of *Ricinus communis* L. A: 254 nm, B: 366nm, and C: Under white light without Derivatization

Chromatographic Patterns:

- ◆ **At 254 nm:** Several high-intensity bands were observed, indicating the presence of phenolic compounds and flavonoids. Most of the samples exhibited a few most intense bands, suggesting a higher concentration of those compounds.
- ◆ **At 366 nm:** Distinct bands corresponding to fluorescent compounds, such as flavonoids, were visible. The intensity and number of bands varied across samples.
- ◆ **Under White Light:** After derivatization, the bands became more distinct, highlighting the presence of saponins and other secondary metabolites.
- ◆ The HPTLC fingerprints serve as a valuable tool for the standardization and quality control of extracts, ensuring consistency and efficacy in their use.

HPLC Analysis

As reference standards gallic acid, rutin, and ellagic acid were used in the HPLC study. The

gallic acid compound exhibited the highest concentration (2.755 $\mu\text{g}/\text{mg}$) in the Gangotri, UK sample. Similarly, the rutin compound showed the highest concentration (2.871 $\mu\text{g}/\text{mg}$) in Bithoor, U.P. Additionally, the ellagic acid compound was found to have the highest concentration (0.765 $\mu\text{g}/\text{mg}$) in Gaumukh, U.K, as shown in Table 3 below. The table below (Table 3) displays the data showing various percentages of the substance in the samples analyzed. The corresponding chromatograms for the reference standards and the plant samples from eleven distinct sites have been shown below (Figs. 2, 3). The rutin, which was found to vary significantly, is known for its ability to strengthen blood vessels, reduce inflammation, and provide antioxidant protection, which could explain the medicinal uses of the species in treating circulatory and inflammatory conditions. Such variations underscore the importance of geographic and environmental factors in determining the phytochemical profiles and, consequently, the medicinal properties of the plant.

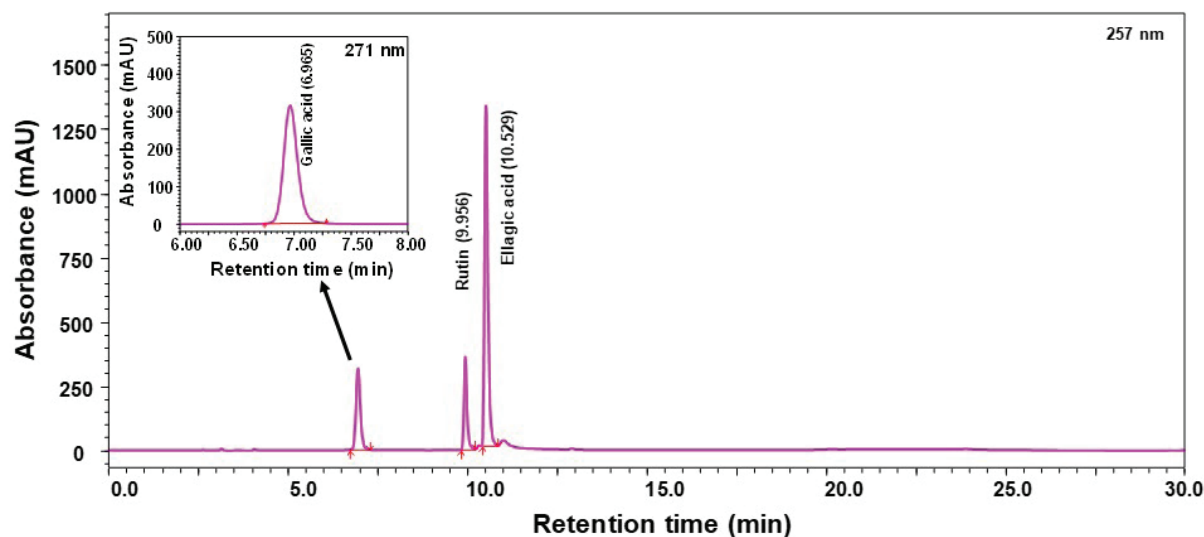


Fig. 2 HPLC chromatogram of standard mix for gallic acid at 271 nm, for rutin and ellagic acid at 257 nm

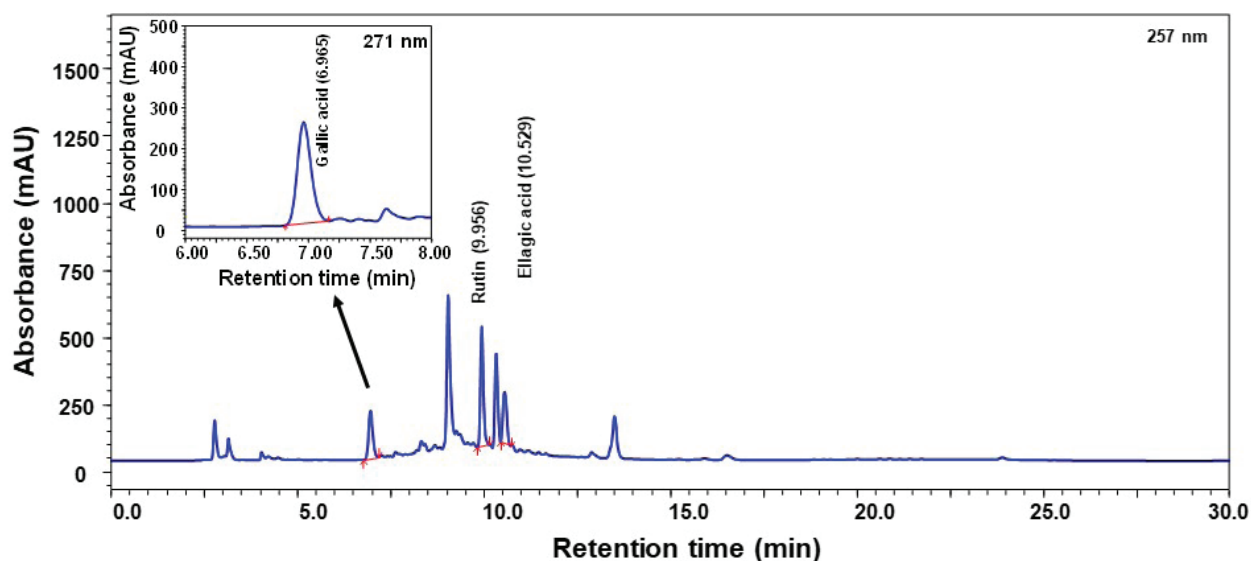


Fig. 3 HPLC chromatogram of *Ricinus communis* L. sample (PRF/CHI/0124/1293) for Gallic acid at 271 nm, for rutin and ellagic acid at 257 nm

Table 3 Content of phytochemicals (in $\mu\text{g}/\text{mg}$) present on *Ricinus communis* L. collected from the different locations

S.No.	Internal code	Samples	Gallic acid	Rutin	Ellagic acid
1	PRF/CHI/0124/1293	Bithoor, Uttar Pradesh	1.690	2.871	0.400
2	PRF/CHI/0124/1294	Dalmau, Uttar Pradesh	0.485	2.157	0.267
3	PRF/CHI/0124/1295	Prayagraj, Uttar Pradesh	0.135	0.832	0.192
4	PRF/CHI/0124/1296	Mirzapur, Uttar Pradesh	0.018	0.031	0.061
5	PRF/CHI/0124/1297	Ballia, Uttar Pradesh	0.632	1.808	0.308
6	PRF/CHI/0124/1298	Revelganj, Bihar	0.079	0.097	0.225
7	PRF/CHI/0124/1299	Patna, Bihar	0.345	0.484	0.213
8	PRF/CHI/0124/1300	Barh, Bihar	0.012	0.052	0.052
9	PRF/CHI/0124/1301	Sahibganj, Jharkhand	0.260	0.710	0.271
10	PRF/CHI/0124/1302	Gaumukh, Uttarakhand	1.519	0.773	0.765
11	PRF/CHI/0124/1303	Gangotri, Uttarakhand	2.755	1.539	0.383

UPLC/MS-QToF Analysis

The analysis resulted in a fast, high-resolution separation with high sensitivity. The qualitative (identification of compounds), and relative quantification (response curve) were obtained for a variety of substances within the complex mixture. The TIC chromatogram as well as the list of identified compounds and their associated parameters in both positive and negative modes have been presented below. A total of 22 compounds were consequently identified in the test sample.

Identified Compounds

- ◆ **Phenolic acids:** Gallic acid, chlorogenic acid, and caffeic acid were identified, each known for their antioxidant properties. The presence of these acids supports the traditional use of *R. communis* in managing

oxidative stress and inflammatory conditions.

- ◆ **Flavonoids:** Besides rutin and quercetin, other flavonoids such as kaempferol were detected. These compounds contribute to the anti-inflammatory and anticancer properties of the plant.
- ◆ **Alkaloids and Terpenoids:** Compounds such as ricinine and castor oil's characteristic triglycerides were also identified. Ricinine is known for its insecticidal and antimicrobial activities, while terpenoids contribute to the plant's anti-inflammatory effects.

The UPLC/MS-QToF analysis provided a molecular fingerprint that could be used for in-depth pharmacological studies and for ensuring the quality of *R. communis*-based products.

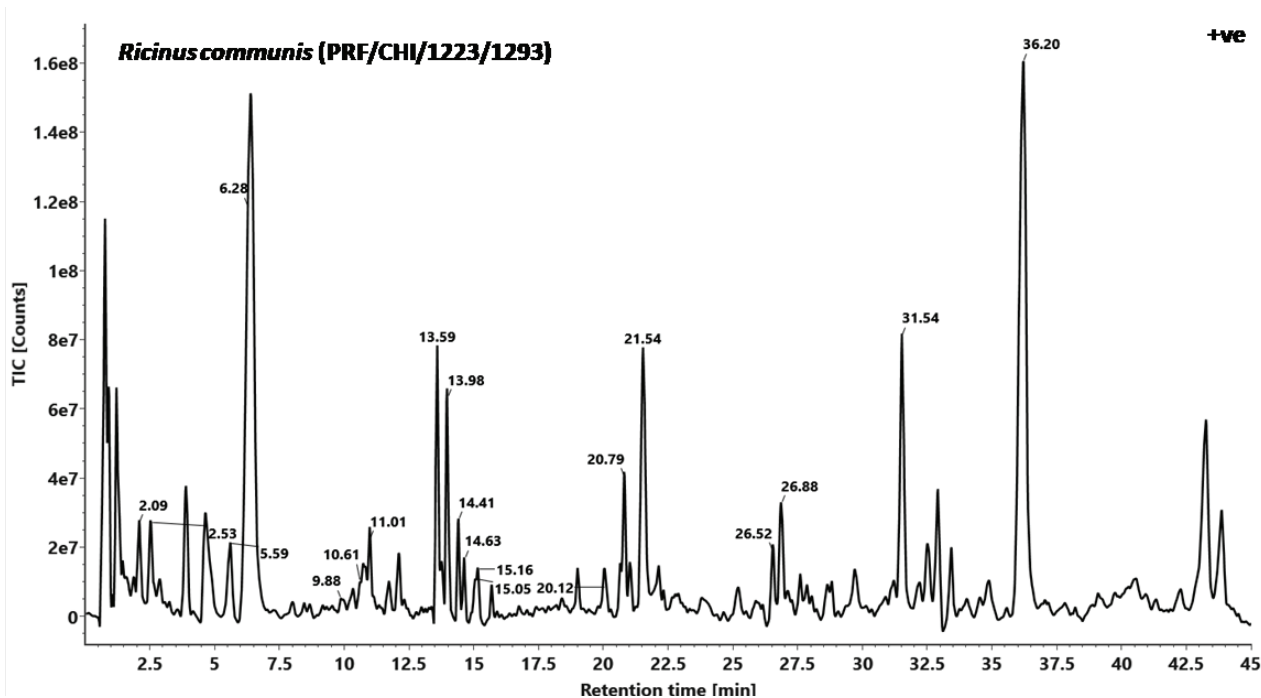


Fig. 4 TIC chromatogram of *Ricinus communis* (PRF/CHI/1223/1293) in positive ionization mode

Table 4 Compound-dependent parameters of analytes/identified compounds in *Ricinus communis* (PRF/CHI/1223/1293) in positive ionization mode

S. N.	Componentname	Formula	Neutalmass (Da)	Observed m/z	Masserror (mDa)	RT (min)	Response	Adducts
1	Gallicacid	C ₇ H ₆ O ₅	170.0215	171.0293	0.5	2.09	339814	+H
2	Phenylalanine	C ₉ H ₉ NO ₂	165.0790	166.0868	0.6	2.53	1240460	+H
3	Tryptophan	C ₁₁ H ₁₂ N ₂ O ₂	204.0899	205.0980	0.8	5.59	916323	+H
4	Ricinine	C ₈ H ₈ N ₂ O ₂	164.0586	165.0660	0.1	6.28	10766273	+H
5	1,2,6-Tri-O-galloyl-b-D-glucose	C ₂₇ H ₂₄ O ₁₈	636.0963	659.0828	-2.7	9.88	54987	+Na
6	1,3,6-Trigalloyl-β-D-glucose	C ₂₇ H ₂₄ O ₁₈	636.0963	659.0823	-3.2	10.61	104678	+Na
7	Corilagin	C ₂₇ H ₂₂ O ₁₈	634.0806	657.0683	-1.5	11.01	67208	+Na
8	Rutin	C ₂₇ H ₃₀ O ₁₆	610.1534	611.1596	-1.1	13.59	7035010	+H
9	Isoquercitrin	C ₂₁ H ₂₀ O ₁₂	464.0955	465.1037	0.9	13.98	4544198	+H
10	Reynoutrin	C ₂₀ H ₁₈ O ₁₁	434.0849	435.0938	1.7	14.41	1312181	+H
11	Kaempferol-3-O-rutinoside	C ₂₇ H ₃₀ O ₁₅	594.1585	595.1653	-0.5	14.63	1332275	+H
12	Astragalin	C ₂₁ H ₂₀ O ₁₁	448.1006	449.1097	1.8	15.05	473271	+H
13	5,7,4'-Trihydroxy-8-C-β-D-flavoneglucoside	C ₂₁ H ₂₂ O ₁₀	434.1213	435.1304	1.8	15.16	761429	+H
14	Naringenin	C ₁₅ H ₁₂ O ₅	272.0685	273.0770	1.2	20.12	714399	+H
15	6''-p-Coumaroylprunin	C ₃₀ H ₂₈ O ₁₂	580.1581	581.1646	-0.8	20.79	2140558	+H
16	Naringenin7-(2-p-Coumaroylglucoside)	C ₃₀ H ₂₈ O ₁₂	580.1581	581.1654	0.1	21.54	4919510	+H
17	kaempferol diacyl rhamnoside	C ₃₉ H ₃₄ O ₁₄	726.1949	727.1998	-2.3	26.52	766090	+H
18	Prunin3'',6''-di-p-coumarate	C ₃₉ H ₃₄ O ₁₄	726.1949	727.2003	-1.8	26.88	3159927	+H
19	9,10-Dihydroxystearic acid	C ₁₈ H ₃₆ O ₄	316.2614	339.2523	1.7	31.54	3354268	+Na
20	Ricinoleicacid	C ₁₈ H ₃₄ O ₃	298.2508	321.2415	1.4	36.20	2845632	+Na

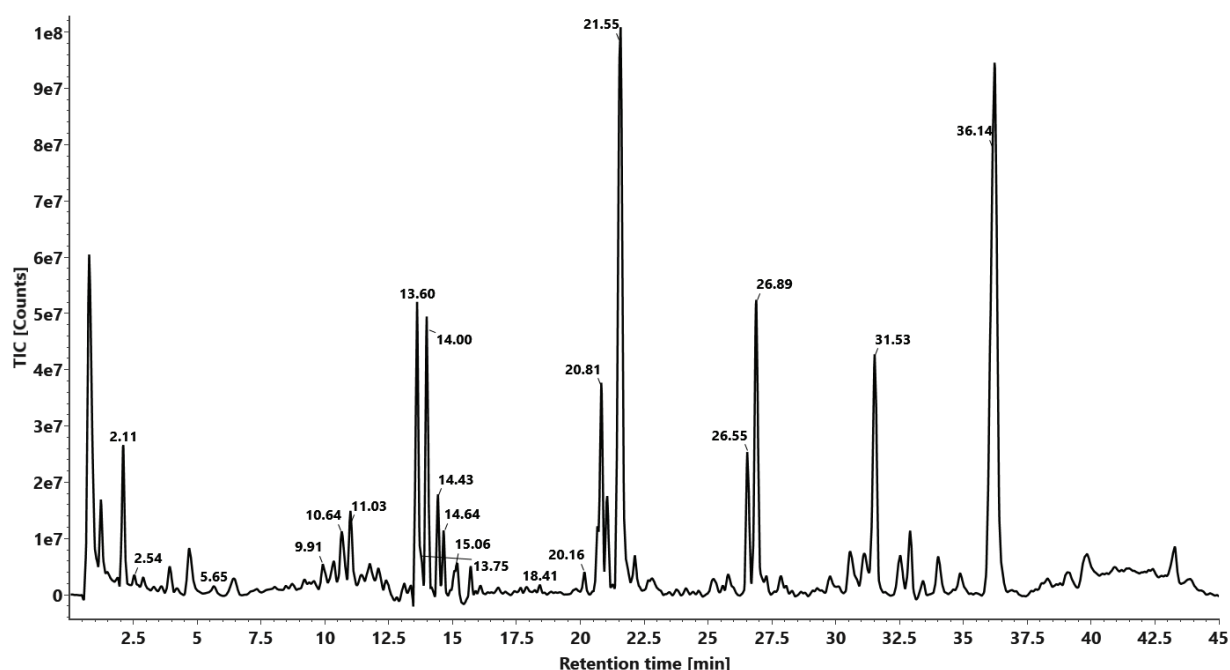


Fig. 5 TIC chromatogram of *Ricinus communis* (PRF/CHI/1223/1293) in negative ionization mode

Table 5 Identified compounds in *Ricinus communis* (PRF/CHI/1223/1293) in negative ionization mode

S. N.	Componentname	Formula	Neutral mass(Da)	Observed m/z	Mass Error (mDa)	RT (min)	Response	Adducts
1	Gallicacid	C ₇ H ₆ O ₅	170.0215	169.0133	-0.9	2.11	2050714	-H
2	Phenylalanine	C ₉ H ₁₁ NO ₂	165.0790	164.0710	-0.7	2.54	1089779	-H
3	Tryptophan	C ₁₁ H ₁₂ N ₂ O ₂	204.0899	203.0812	-1.4	5.65	229710	-H
4	1,2,6-Tri-O-galloyl- b-D-glucose	C ₂₇ H ₂₄ O ₁₈	636.0963	635.0901	1.1	9.91	568527	-H
5	1,3,6-Trigalloyl- β-D-glucose	C ₂₇ H ₂₄ O ₁₈	636.0963	635.0899	0.9	10.64	1292526	-H
6	Corilagin	C ₂₇ H ₂₂ O ₁₈	634.0806	633.0745	1.2	11.03	847931	-H
7	Rutin	C ₂₇ H ₃₀ O ₁₆	610.1534	609.1466	0.5	13.60	7998464	-H
8	Ellagicacid	C ₁₄ H ₆ O ₈	302.0063	300.9969	-2.1	13.75	373344	-H
9	Isoquercitrin	C ₂₁ H ₂₀ O ₁₂	464.0955	463.0867	-1.5	14.00	5272783	-H
10	Reynoutrin	C ₂₀ H ₁₈ O ₁₁	434.0849	433.0759	-1.7	14.43	2128431	-H
11	Kaempferol-3-O-rutinoside	C ₂₇ H ₃₀ O ₁₅	594.1585	593.1519	0.7	14.64	1594885	-H

S. N.	Componentname	Formula	Neutral mass(Da)	Observed m/z	Mass Error (mDa)	RT (min)	Response	Adducts
12	Astragalin	C ₂₁ H ₂₀ O ₁₁	448.1006	447.0919	-1.4	15.06	617615	-H
13	5,7,4'-Trihydroxy-8-C-β-D-flavanoneglucoside	C ₂₁ H ₂₂ O ₁₀	434.1213	433.1119	-2.1	15.18	589793	-H
14	Quercetin	C ₁₅ H ₁₀ O ₇	302.0427	301.0334	-2.0	18.41	150635	-H
15	Naringenin	C ₁₅ H ₁₂ O ₅	272.0685	271.0596	-1.6	20.16	448741	-H
16	6''-p-Coumaroyl-prunin	C ₃₀ H ₂₈ O ₁₂	580.1581	579.1523	1.5	20.81	4682536	-H
17	Naringenin 7-(2-p-Coumaroylglucoside)	C ₃₀ H ₂₈ O ₁₂	580.1581	579.1520	1.2	21.55	7997917	-H
18	Kaempferoldiacyl-rhamnoside	C ₃₉ H ₃₄ O ₁₄	726.1949	725.1910	3.5	26.55	3983543	-H
19	Prunin3'',6''-di-p-coumarate	C ₃₉ H ₃₄ O ₁₄	726.1949	725.1911	3.5	26.89	7036013	-H
20	9,10-Dihydroxysearic acid	C ₁₈ H ₃₆ O ₄	316.2614	315.2522	-1.9	31.53	7066702	-H
21	Ricinoleic acid	C ₁₈ H ₃₄ O ₃	298.2508	297.2421	-1.5	36.14	10156089	-H

Conclusion

The comprehensive phytochemical analysis of *Ricinus communis* leaf samples collected from 11 diverse locations spanning the Ganga River basin offers valuable insights into the variations in phytochemical composition across different geographical regions. Through rigorous testing for tannin, saponin, polyphenol, and flavonoids, coupled with HPTLC fingerprinting at short and long wavelengths, and HPLC quantification of gallic acid, rutin, and ellagic acid, a detailed profile of the leaf samples was obtained. The

banding patterns of phytochemicals observed under different wavelengths and white light revealed similarities across the samples, albeit with variations in intensity, indicating differences in phytochemical concentration among the locations. Notably, gallic acid exhibited the highest concentration in the Gangotri, Uttarakhand sample, underscoring the significance of geographical factors in influencing phytochemical content. Similarly, rutin displayed its highest concentration in Bithoor, Uttar Pradesh, while ellagic acid

reached its peak concentration in Gaumukh, Uttarakhand. Lastly, the study also employed advanced hyphenated techniques, UPLC/MS-QToF, for the identification and quantification of a total of 22 compounds. This advanced methodology allowed for a highly detailed and accurate characterization of the chemical constituents present in the species.

These findings underscore the importance of geographical location in determining the phytochemical composition of *Ricinus*

communis leaves, suggesting potential implications for their medicinal and pharmacological applications. Further research exploring the underlying factors driving these variations could contribute to a deeper understanding of plant secondary metabolite biosynthesis and ecological adaptations. Such insights are crucial for harnessing the therapeutic potential of natural products and for the conservation and sustainable utilization of plant biodiversity in the Ganga River basin and beyond.

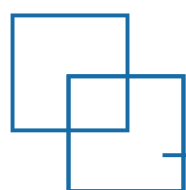
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CHAPTER

06

Insilico Analysis Against Gastric Cancer



INTRODUCTION

Gastric cancer, a malignant neoplasm of the digestive tract, represents a critical global health challenge due to its substantial morbidity and mortality rates (Tu et al., 2021). The disease is more prevalent in males than in females (Fathi et al., 2023). In most cases, diseases tend to remain asymptomatic until they advance significantly, often leading to their detection at an already malignant stage (Vetrivel et al., 2020). The disease usually manifests in the form of nausea and vomiting, with a small number of patients dealing with black stools due to upper gastrointestinal bleeding (Zhang and Guo, 2023). Surgical resection, considered the optimal treatment for patients in the early stages of the disease, faces obstacles due to delayed diagnoses and frequently leads to postoperative recurrence and mortality. Moreover, chemotherapeutic medications yield suboptimal outcomes and are constrained by their high toxicity. Addressing these challenges emphasizes the urgent need for the development of innovative drugs that offer heightened efficacy while minimizing cellular toxicity (Vetrivel et al., 2020; Tu et al., 2021). Natural remedies are a preferred option due to their minimized adverse effects and remarkable biological capacity (Tu et al., 2021). Moreover, the efficacy of numerous chemotherapy approaches is compromised by multidrug resistance. This effectiveness can be augmented through the incorporation of anti-cancer phytochemicals in conjunction with anticancer medications (Guzmán et al., 2020).

The acyl-CoA thioesterase gene (ACOT) enzyme family, integral to mammalian fatty acid metabolism, plays a crucial role by facilitating the hydrolysis of fatty acyl-CoA esters, releasing coenzyme A and non-esterified fatty acids. This enzymatic action coordinates several vital cellular processes such as β -oxidation, lipid biosynthesis, signal transduction, and various metabolic functions (Xu et al., 2020). Among the diverse members within this family, ACOT4 is localized within peroxisomes (Li et al., 2019). Notably, recent studies have associated ACOT4 expression with an unfavorable prognosis in gastric cancer (GC) patients (Ni et al., 2021). Due to its implications in cancer progression, ACOT4 has been chosen as the subject of investigation for the current study.



Ricinus communis L. is hosted by family Euphorbiaceae and is well known for its traditional and ethnomedicinal potential worldwide (McNeil et al., 2021; Khalid et al., 2022). Also, it is famous as “castor oil plant” and “castor bean”, the plant reaches a height of 5 to 10 m and a trunk thickness of 15 cm (Kebede and Shibeshi, 2022). The plant is known to have its roots in Africa and was further introduced in India and China. Presently, the plant can be cultivated anywhere in the world (Agyenim-Boateng et al., 2019). As depicted by numerous studies, castor plant possesses a wide range of medicinal properties. For instance, consumption of freshly squeezed leaves along with milk helps in the treatment of rabies patients (Mintiwab and Jeyaramraja, 2021). Since ancient times, castor oil has been employed as a laxative and inducer of labor pain in pregnant women. Likewise, the oil is efficient at relieving soreness, foot pain and back ache. Additionally, the oil is used as an eye-drop for dry eyes, an edema reducing ingredient, as eye-drops for lipid-deficient dry eyes, and as an ingredient for reducing edema and alleviating skin diseases (Agyenim-Boateng et al., 2019; Rani and Sood, 2021). Phytochemical investigations of the plant have revealed presence of alkaloids, flavonoids, phenols, tannins, cardiac glycosides, quinones, saponins, terpenoids, phlobatannins and volatile oils (Bari et al., 2021). However, the presence of toxic compound “ricin” has posed as a threat in reintroduction of plant globally (Alsubeie et al., 2023).

As a result of the previously mentioned problem, a comprehensive *in silico* study was conducted with targeted protein ACOT-4 associated with GC. Furthermore, our results have established a strong candidature named 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine to be used as a drug-like molecule for preventing gastric cancer. To elucidate their dynamic and thermodynamic properties and to support the molecular docking results, molecular dynamics simulation was performed on the compound. Furthermore, to ensure compound's safety and efficacy in the treatment, its drug-likeness, physicochemical properties, and ADMET were investigated.

Etiology of Gastric Cancer

The progression of GC is generally linked with the accumulation of mutations in multiple genes (Saleem et al., 2022). Proto-oncogene B, located on chromosome 17, has emerged as a key contributor to tumor formation in GC. In the context of cancer progression, angiogenesis assumes a crucial role. The genes VEGFR-1 and VEGFR-2 actively participate in angiogenesis, engaging in processes such as the binding of vascular endothelial growth factor (VEGF) to vascular cells and downstream cell signaling (Sampath et al., 2022). Geographically, developing countries witness 50% of new gastric cancer cases, with Central and South America, Eastern Europe, and East Asia being particularly

affected regions (Machlowska et al., 2020). Lifestyle factors significantly contribute to the initiation of this disease. Individuals engaging in tobacco, alcohol, and the consumption of salty and preserved foods are at an elevated risk of susceptibility to gastric cancer (Jin et al., 2020). In addition to various contributing factors, *Helicobacter pylori* infection accounts for approximately 75% of gastric cancer cases, as documented by Baj et al. (2020). Some studies have explored the correlation between the expression levels of long non-coding RNAs (lncRNAs) in gastric cancer tissues and tumor characteristics, including depth, distant metastasis, and clinical stage (Ghafouri-Fard and Taheri, 2020).

Reported Therapeutic Use

As indicated by existing literature evidences, *R. communis* is a therapeutically blessed plant. A study showed the anti-replicative activity potential of its leaf extract against hepatitis A virus (Elkousy et al., 2021). Similarly, the plant fruit extract was found to possess anti-cancer effect against estrogen positive MCF-7 and triple negative MDA-MB-231 breast cancer cells. The extract depicted a dose-dependent cytotoxicity and significant anti-metastatic potential against

the treated cell lines (Majumder et al., 2019). In a parallel study, the efficacy of this plant against MCF7 breast cancer cell line, A2780 ovarian cancer cell line and HT29 colorectal cancer cell line was described (Khalid et al., 2022). Additionally, the plant extract exhibited significant reduction in the interleukin levels and elevation in IFN- γ levels, presenting their immunomodulatory effects (Naji et al., 2019). The detailed therapeutic efficacy of the plant is presented in Table 1.

Table 1 List of therapeutic uses of *R. communis*

Part	Therapeutic Use	Reference
Leaves	Cervical cancer	(Zarai et al., 2012)
Leaves	Hepatitis A virus infection	(Elkousy et al., 2021)
Root	Anti-inflammatory	(Ilavarasan et al., 2006)
Leaves, stem, and root	Anti-fungal	(Khan et al., 2011)
Stem bark	Male contraceptive	(Nath et al., 2013)
Seed	Breast, ovarian and colorectal cancer	(Khalid et al., 2022)
Root	Diabetes	(Shokeen et al., 2008)
Root	Asthma	(Taur et al., 2011)
Seed	Colon cancer, Liver cancer, Breast cancer, Cervix cancer and Prostrate cancer	(Prakash et al., 2014)
Leaves	Hepatoprotective agent	(Visen et al., 1992)
Seed	anti-convulsant	(Tripathi., et al., 2011)
Leaves	Antinociceptive	(Taur et al., 2011)
Leaves	Analgesic	(Ladda., et al., 2014)
Root and bark	Contractile activity	(Kaingu et al., 2012)
Leaves	Melanoma	(Darmanin et al., 2009)
Leaves	Hyperlipidemia and pancytopenia	(Oyewole et al., 2016)
Fruit	Amnesia	(Ferraz., et al., 1999)
Leaves	Anti-bacterial	(Abew et al., 2014)
Leaves	Hepatitis	(Babu et al., 2014)
Leaves	Neuroprotection and Ischemia	(Ahmad et al., 2021)
Leaves	Anti-arthritis	(Hussain et al., 2021)
Leaves	Muscle atrophy	(Lee et al., 2022)

Materials and Methods

Protein Structure Retrieval and Preparation

The crystal structure of human acyl-CoA thioesterases 4 in complex with undecan-2-one-CoA inhibitor (PDB ID: 4GAH), obtained via X-RAY diffraction method at a resolution of 2.30 Å was retrieved from RCSB protein data bank (<https://www.rcsb.org/>) (Fig. 1). To generate accurate predictions, any of the

associated water molecules or heteroatoms were removed from the structures with the assistance of PyMol (<https://pymol.org/2/>). Further, the protein structures were repaired using protein repair and analysis server (<https://www.protein-science.com/>) by adding missing hydrogens, side chains and secondary structure elements. The final structure was saved in PDB format for further studies.

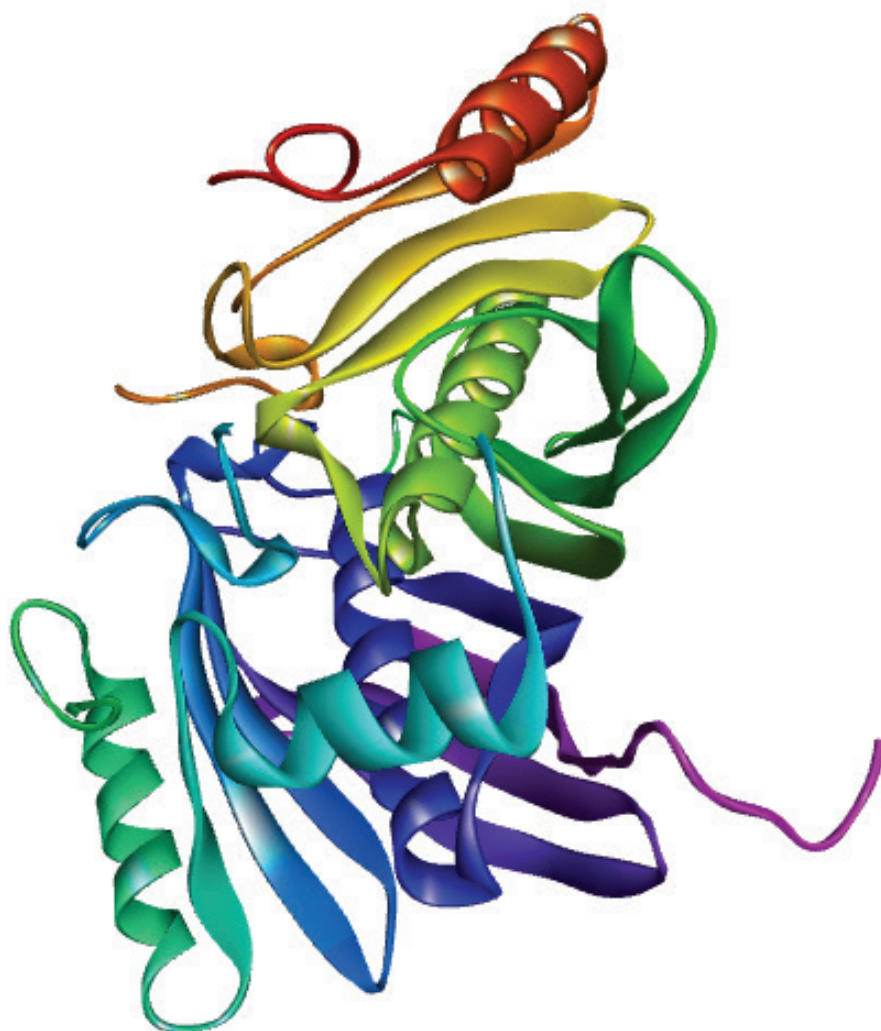


Fig. 1 Human acyl-CoA thioesterases 4

Phytochemical Library Preparation

Extensive literature survey was performed to obtain a list of 73 phytoconstituents present in *R. communis*. The three-dimensional structures of the compounds in SDF format were retrieved from PubChem database (<https://pubchem.ncbi.nlm.nih.gov/>). In addition, the SDF files were converted into PDB format by utilizing Open Babel GUI (https://openbabel.org/wiki/Main_Page), to facilitate the process of molecular docking.

Rule of Five (R05)

For initial prescreening of phytoconstituents, an online web-based platform, ADMET lab 2.0 (<https://admetmesh.scbdd.com/>) was utilized to predict the drug-likeness of the compounds. For small molecules, it is an empirical rule of thumb to assess their physicochemical aspects, to refine their drug ability. In the present study, we analyzed several properties including molecular weight (MW), partition coefficient (LogP), number of hydrogen bond acceptors (nHA) and number of hydrogen bond donors (nHD). As these attributes form the foundation for the Lipinski rule of five, any molecule deviating from the threshold values was eliminated from further analysis (Lipinski, 2004).

Molecular Docking

In the current study, PyRx software (<https://pyrx.sourceforge.io/>) was utilized for the high-throughput molecular docking study. The

prepared PDB structures of target proteins and plant phytoconstituents were imported into the software and were processed to generate the respective PDBQT files. Blind molecular docking was performed with grid box sizes, $x = 54.4804090214$; $y = 66.4783121109$ and $z = 62.9092420006$. Moreover, the protein-ligand complexes were prepared using PyMol. These complexes were imported to Discovery Studio Visualizer v21.1.0.20298 (<https://discover.3ds.com/discovery-studio-visualizer-download>) for visualization of various interactions formed between the target and phytoconstituents.

Bioavailability Radar and Bioactivity Score

Drug-likeness of screened candidate with best binding energy was analyzed in a comprehensive way using SwissADME web-based tool (<http://www.swissadme.ch/index.php>). To do so, physicochemical properties such as size (MW), lipophilicity (XLOGP3), polarity (TPSA), solubility (LogS), flexibility (fraction Csp3), and saturation (rotatable bonds) were investigated and a bioavailability radar diagram representing these parameters was obtained (Lipinski et al., 2012). The region highlighted in pink delineates the optimal parameter values, and substantial deviations from these values on a significant scale imply that the ligand may not possess favorable oral bioavailability (Fig.3) (Daina et al., 2017). Additionally, the bioactivity scores were determined by using Molinspiration software (<http://www.molinspiration.com/>). Parameters analyzed include ion channel modulator (ICM), nuclear

receptor ligand (NRL), protease inhibitor (PI), enzyme inhibitor (EI), and G protein-coupled receptor ligand (GPCR ligand).

In silico ADMET analysis

After molecular docking studies of all the compounds with targeted protein of NiV, pharmacokinetics parameters such as ADMET (absorption, distribution, metabolism, excretion and toxicity) of the best candidate were investigated using ADMET LAB 2.0 (<https://admetmesh.scbdd.com/service/evaluation/index>). ADMET constitutes a crucial aspect of drug design and development, encompassing the assessment of significant pharmacokinetic parameters (Olasupo et al., 2020). ADMET properties include absorption (Caco-2 permeability, MDCK permeability, probability of being Pgp-inhibitor or Pgp-substrate, human intestinal absorption, human oral bioavailability 20% and human oral bioavailability 30%); distribution: (plasma protein binding, volume distribution, blood-brain barrier penetration, and fraction unbound in plasms); metabolism (CYP 1A2 / 2C19 / 2C9 / 2D6 / 3A4 inhibitor and CYP 1A2 / 2C19 / 2C9 / 2D6 / 3A4 substrate); excretion (clearance of a drug and half-life of a drug); toxicity (hERG Blockers, human hepatotoxicity, drug-induced liver injury, Ames test for mutagenicity, rat oral acute toxicity, maximum recommended daily dose, skin sensitization, carcinogenicity, eye

corrosion/irritation and respiratory toxicity) (Xiong et al., 2021).

Molecular Dynamics Simulation

Based on molecular docking analysis, top phytochemical from *R. communis* was further selected for molecular dynamics (MD) simulation to examine its stability and intermolecular interactions using Desmond molecular dynamics study software (Bowers et al., 2006). Using the protein preparation wizard of the Desmond-maestro interface, all protein-ligand contacts were preprocessed and improved. The system was configured for each complex using the SPC model of solvent, an orthorhombic box simulation box was calculated using the buffer method with a distance of $10 \times 10 \times 10$ Å. Later, counter ions (Na^+ or Cl^-) were added for neutralization, system's concentration was set to 0.15 M and OPLS3e force field was applied to the system. This generated system was simulated for 100 ns in a minimized system in the NPT ensemble. After simulation, the trajectory was analyzed using parameters such as root mean square deviation (RMSD), root mean square fluctuation (RMSF), protein-ligand interactions, radius of gyration of the lead compound, and ligand torsion analysis using the simulation interaction diagram utility of the Desmond.

Results and Discussion

Despite of cutting-edge research and development taking place to produce innovative solutions to combat GC, it has become the fifth most common cancer and the third most common cause of cancer death globally (Smyth et al., 2020). The sole objective of this study is to identify potential compounds from *R. communis* with good binding affinity against GC-related protein, using diverse computational tools.

Preliminary Screening of Drug likeness

In the pursuit of creating a highly effective drug with minimal adverse effects, preliminary screening based on drug-likeness

is a crucial step. To conduct this preliminary screening, Lipinski's Rule of Five was utilized for evaluating all the phytochemicals derived from *R. communis*. A compound demonstrates favorable oral bioavailability when its molecular weight (MW) $\leq$ 500 Da, hydrogen bond donors (HbD) $\leq$ 5, hydrogen bond acceptors (HbA) $\leq$ 10, and an octanol-water partition coefficient $\log P \leq 5$ (Lipinski, 2004). Compounds that violated more than one parameter were excluded, while the remaining compounds were identified as ligands for the subsequent docking study. Out of the total 73 phytoconstituents, 56 candidates successfully passed Lipinski's rule and were carried forward for further analysis (Table 2).

Table 2 Screening of phytoconstituents based on Lipinski's rule

Phytochemicals	LogP	MW	Vol	nHA	nHD	nV
Pyrrolizin-1,7-dione-6- carboxylic acid, methyl(ester)	-0.276	197.07	185.356	5	0	0
Tertbutyloxyformamide , N-methyl-N-[4-(1- pyrrolidinyl)-2-butynyl	2.598	252.18	273.808	4	0	0
1,2,4-Triazino[5,6- E][1,2,4]-tri-azine-3,6- dione, hexahydro	-2.132	172.07	138.916	8	6	1
Deoxyspergualin	-2.412	387.3	398.027	10	10	1
Aminoacetamide , Nmethyl-N-[4-(1- pyrrolidinyl)-2-butynyl]-	-0.111	209.15	224.127	4	2	0
Pregna-3,5-dien-9-ol-20- one	3.588	314.22	347.217	2	1	0
2-Methoxy-4- vinylphenol	2.251	150.07	162.698	2	1	0
Ascaridole epoxide	2.537	166.1	170.791	2	0	0
Trans-3,4,5-Trimethoxy β -nitrostyrene	1.923	239.08	232.021	6	0	0

Phytochemicals	LogP	MW	Vol	nHA	nHD	nV
3- (N,NDimethylaurylammonio)propanesulfonate	0.818	336.26	359.783	4	1	0
Tetraacetyl-d-xylonic nitrile	-0.226	343.09	322.354	10	0	0
Pentaerythritol , bis-O- (9- borabicyclo[3.3.1]non-9- yl)-di-O-methyl	5.629	404.33	59295973.9	4	0	0
1H-Purin-2-amine, 6- methoxy-N-methyl-	0.822	179.08	165.744	6	2	0
1,2- Cyclopentanedicarboxylic acid 4-(1,1- dimethylethyl)-dimethyl ester	2.979	242.15	254.736	4	0	0
Glycyl-D-asparagine	-2.783	189.07	172.574	7	6	0
1-Tetradecanamine, N,N-dimethyl	6.405	241.28	296.289	1	0	1
2,7-Diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine	1.539	355.11	352.621	7	1	0
Propiolic acid, 3-(1- hydroxy-2-isopropyl-5- methylcyclohexyl)-, ethyl ester	3.548	252.17	277.901	3	1	0
Phytol	7.764	296.31	360.63	1	1	1
Ricinoleic acid	5.459	298.25	340.982	3	2	0
Gallic acid	0.645	170.02	154.477	5	4	0
Protocatechuic acid	1.041	154.03	145.687	4	3	0
Gentisic acid	1.636	154.03	145.687	4	3	0
Catechin	1.142	290.08	279.249	6	5	0
Chlorogenic acid	-0.162	354.1	331.473	9	6	1
Vanillic acid	1.396	168.04	162.983	4	2	0
Caffeic acid	1.43	180.04	177.642	4	3	0
Epicatechin	1.142	290.08	279.249	6	5	0
p-Coumaric acid	1.923	164.05	168.852	3	2	0
Vitexin	0.33	432.11	404.357	10	7	1
3-Pyridinecarbonitrile	0.385	104.04	112.587	2	0	0
Lupeol	7.291	426.39	490.807	1	1	1

Phytochemicals	LogP	MW	Vol	nHA	nHD	nV
Ricinine	-0.07	164.06	164.76	4	0	0
Glycerol 2-stearate	6.235	358.31	404.297	4	2	0
Glycerol 2-palmitate	5.275	330.28	369.705	4	2	0
α -Tocopherol	9.624	430.38	502.698	2	1	1
Sitosterol	7.663	414.39	482.068	1	1	1
Stigmasterol	7.436	412.37	479.432	1	1	1
Tributyl acetyl citrate	3.942	402.23	414.252	8	0	0
1,2,3,4-Butanetetrol, [S-(R*,R*)]-	-1.861	278.01	219.672	8	2	0
Ribitol	-2.352	152.07	138.988	5	5	0
3-Ethoxy-1,2-propanediol	-0.598	120.08	121.407	3	2	0
DL-Arabinose	-2.039	150.05	136.351	5	4	0
p-Dioxane-2,3-diol	-1.643	120.04	104.345	4	2	0
D-Limonene	4.368	136.13	167.687	0	0	0
Dodecanoic acid ,3-hydroxy-	3.46	216.17	239.843	3	2	0
Methyl 6-oxoheptanoate	0.455	158.09	168.022	3	0	0
Dithiocarbamate, S-methyl-,N-(2-methyl-3-oxobutyl)-	0.715	191.04	181.16	2	1	0
Geranyl isovalerate	5.559	238.19	277.667	2	0	0
Phenol,4-(1,1,3,3-tetramethylbutyl)-	4.981	206.17	243.025	1	1	0
Picrotoxinin	1.106	292.09	270.046	6	1	0
Phthalic acid	1.187	166.03	160.346	4	2	0
13-Hexyloxacyclotridec-10-en-2-one	6.402	280.24	323.635	2	0	1
Ergost-5-en-3-ol	7.308	400.37	464.772	1	1	1
γ -Sitosterol	7.663	414.39	482.068	1	1	1
Fucosterol	7.447	412.37	479.432	1	1	1

LogP: partition coefficient; MW: molecular weight; vol: volume; nHA: number of hydrogen bond acceptor; nHD: number of hydrogen bond donor; nV: number of violations

Molecular Docking Analysis

Molecular docking plays a vital role as a computational tool in the field of drug discovery. It was performed on ligands that had undergone the prescreening. In the current study, the selected targeted protein is docked against screened phytoconstituents to examine their binding affinity. The docking results of top 10 lead compounds against each studied protein are detailed in Table 3. On the basis of Lipinski violation and docking results evaluation, it was found that vitexin was able to bind the target protein with highest binding affinity of -9.8 kcal/mol and 2 hydrogen bonds

with residue ASP B: 161 and THR B: 82, followed by pregna-3 5-dien-9-ol-20- (-9.4 kcal/mol and 1 hydrogen bond with TYR B: 79), 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine (-9 kcal/mol and 2 hydrogen bonds with MET B: 169; GLY A: 153), stigmasterol (-9 kcal/mol, 0 hydrogen bonds) and chlorogenic acid with a binding affinity of -8.6 kcal/mol and 4 hydrogen bonds with residues ARG B: 186; ILE B: 188; THR A: 177; GLY A: 165 (Table 4; Fig. 2). Among these molecules, 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine depicted acceptable binding energy and no Lipinski's rule violation, therefore, was proceed forward for further analysis.

Table 3 Molecular docking results of top 10 phytoconstituents

Ligand	Binding Affinity
Vitexin	-9.8
Pregna-3 5-dien-9-ol-20-	-9.4
2,7-Diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine	-9.0
Stigmasterol	-9.0
Chlorogenic acid	-8.6
Gamma-Sitosterol	-8.6
Catechin	-8.3
Epicatechin	-8.2
Lupeol	-8.2
Ergost-5-en-3-ol	-7.9

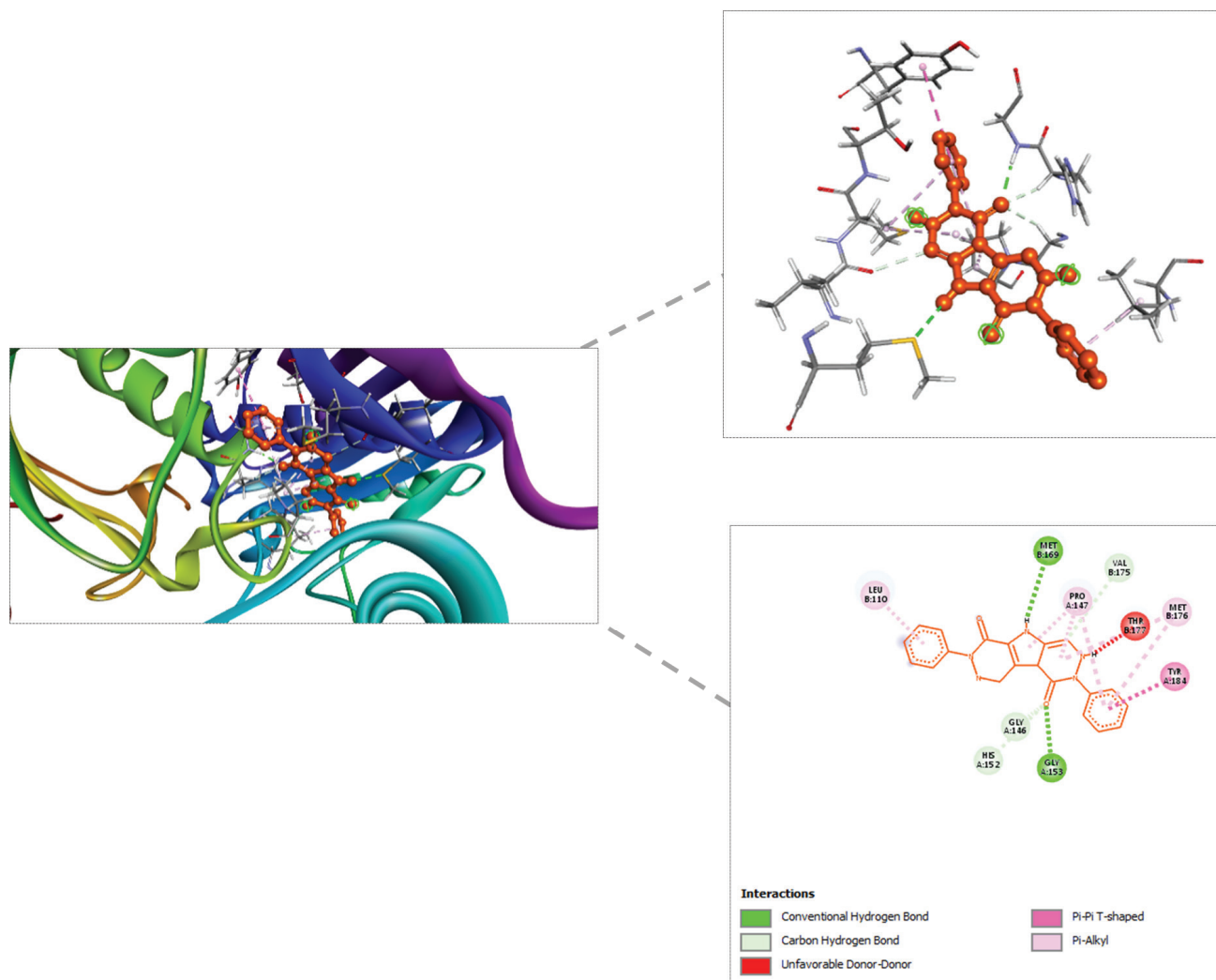


Fig. 2 Illustration of ACOT4-2,7-Diphenyl-1,6-dioxopyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine complex

Table 4 Hydrogen bond interactions formed by the top compounds

Ligand	H-bonds
Vitexin	ASP B: 161; THR B: 82
Pregna-3 5-dien-9-ol-20-	TYR B: 79
2,7-Diphenyl-1,6-dioxopyridazino[4,5:2',3'] pyrrolo[4',5'-d]pyridazine	MET B: 169; GLY A: 153
Stigmasterol	No H-bonds
Chlorogenic acid	ARG B: 186; ILE B: 188; THR A: 177; GLY A: 165

Bioavailability Radar and Bioactivity Score

Bioavailability is an important parameter of the drug development process (Wei et al., 2022). In this study, bioavailability was evaluated for candidate with best binding affinity *i.e.* 2,7-Diphenyl-1,6-dioxopyridazino[4,5:2',3']

pyrrolo[4',5'-d]pyridazine. As shown in Fig. 3, the compound showed size, lipophilicity, flexibility, polarity, and insolubility within the permissible range, however, the instauration of the computed parameter deviated minutely from the set boundary. Overall, the compound depicted acceptable bioavailability parameters with a score of 0.55.

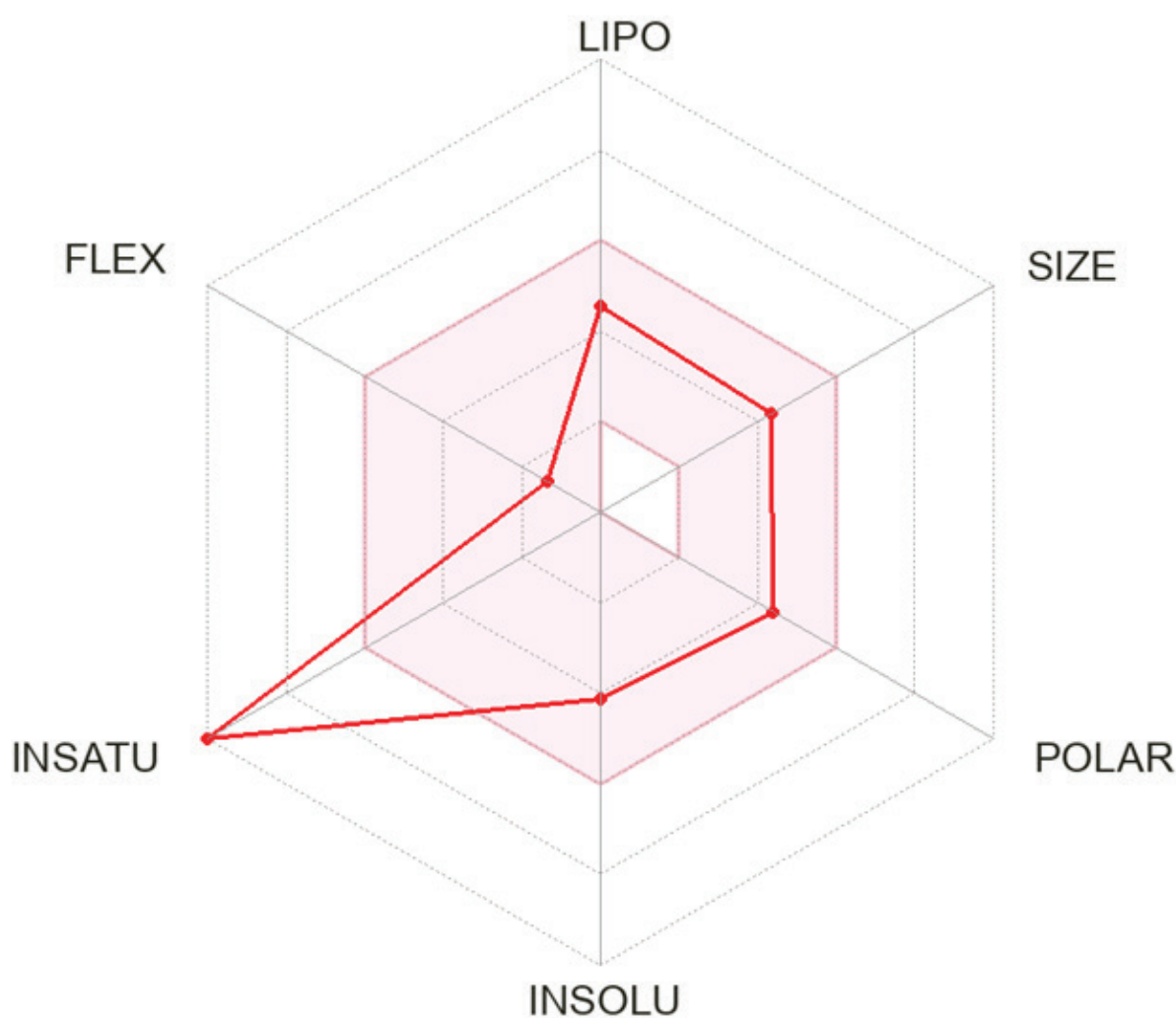


Fig. 3 Bioavailability radar diagram of 2,7-Diphenyl-1,6-dioxopyridazino[4,5:2',3'] pyrrolo[4',5'-d]pyridazine

In addition, the bioactivity scores for 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine such as G protein coupled receptor (GPCR) ligand, ion channel modulator, kinase inhibitor, nuclear receptor ligand and protease inhibitor were assessed using Molinspiration Online tool. As illustrated in Fig. 4, it was found that the compound depicted potent kinase inhibitor activity and moderate rest of the activities.

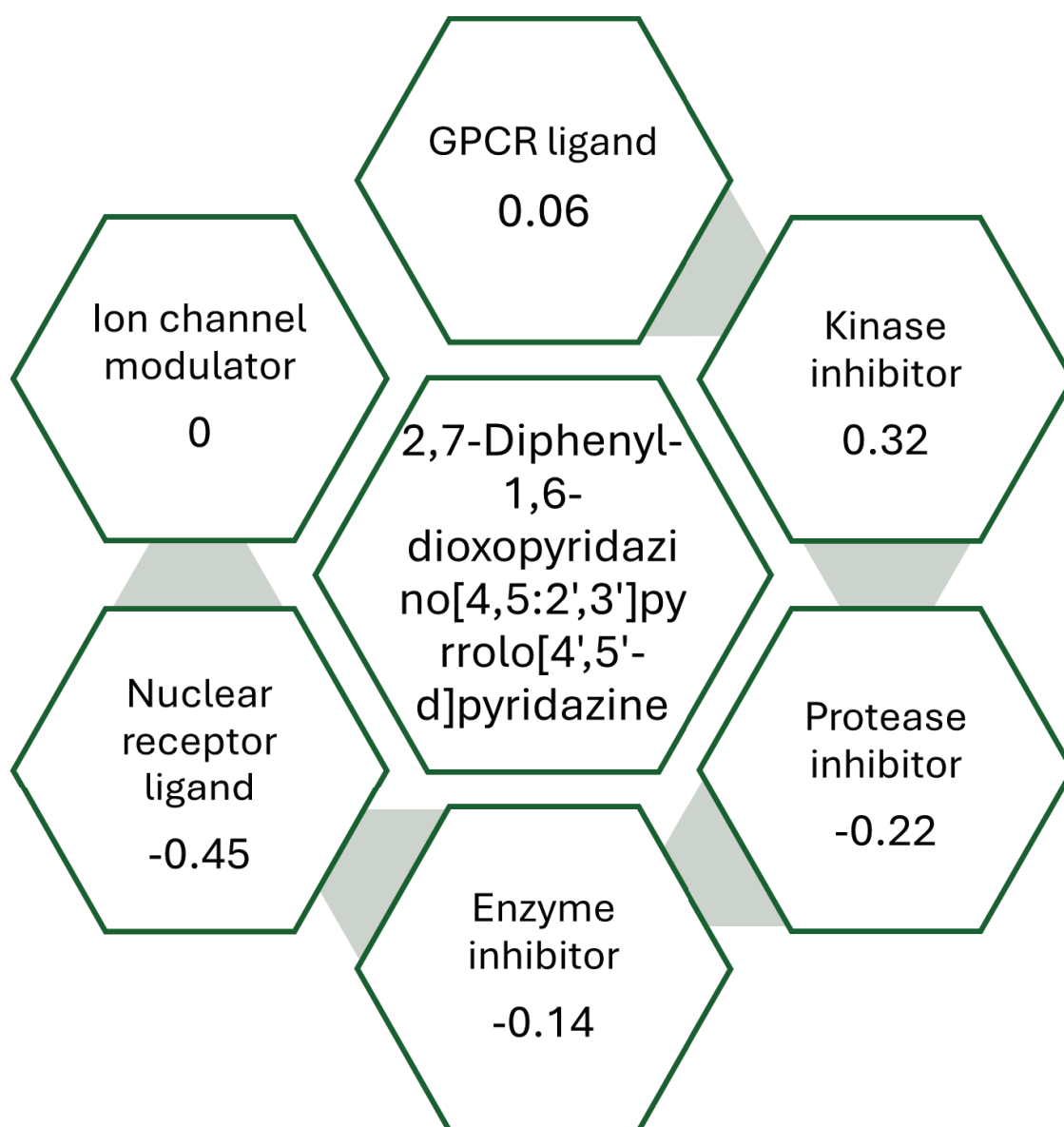


Fig. 4 Bioactivities of 2,7-Diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine

In Silico ADMET Analysis

Administering medication orally is the most convenient method for patients. When a drug is taken orally, it must be absorbed through the epithelial lining of the small intestine (Azman et al., 2022). The ADMET properties of the compound were assessed based on the explanations given on the ADMET lab 2.0 website. As presented in Table 5, all the absorption parameters were found to be excellent. In distribution, VDss were found to be excellent, and BBB was moderate, however, PPB and Fu were poor. Further, for metabolism in all cases, the probability of being CYP1A2, CYP2C19, CYP2C9, CYP2D6

and CYP3A4 inhibitor or substrate was greater than 0. However, both the parameters under excretion properties were found to be poor. Lastly, the compound was assessed for its toxicity profile revealing low toxicity parameters in all cases except for DILI (Drug-induced liver injury) and respiratory toxicity. The ADMET results presented in Table 5 revealed that the compound 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine demonstrated significant parameters that make it suitable for use as a drug. It can easily dissolve in the body and meets the ADMET criteria and drug-likeness standards.

Table 5 *In silico* ADMET analysis of 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine

Properties		Compound
Absorption	Pgp-inh	0.116
	Pgp-sub	0
	HIA	0.012
	F(20%)	0.002
	F(30%)	0.004
	Caco-2	-5.057
	MDCK	7.37E-06
Distribution	BBB	0.505
	PPB	92.04%
	VDss	0.778
	Fu	4.18%
Metabolism	CYP1A2-inh	0.78
	CYP1A2-sub	0.063

Properties		Compound
	CYP2C19-inh	0.484
	CYP2C19-sub	0.545
	CYP2C9-inh	0.815
	CYP2C9-sub	0.937
	CYP2D6-inh	0.152
	CYP2D6-sub	0.28
	CYP3A4-inh	0.35
	CYP3A4-sub	0.802
Excretion	CL	0.905
	T12	0.281
Toxicity	hERG	0.019
	H-HT	0.479
	DILI	0.989
	Ames	0.028
	ROA	0.021
	FDAMDD	0.358
	SkinSen	0.44
	Carcinogenicity	0.224
	EC	0.006
	EI	0.304
	Respiratory	0.947

Molecular Dynamics Simulations

On the basis of molecular docking, bioavailability, bioactivity, and ADMET analysis, 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3'] pyrrolo[4',5'-d]pyridazine fulfilled all the parameters and was therefore, subjected to

molecular dynamics simulations for 100 ns. The dynamic behaviors or molecular stability of 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3'] pyrrolo[4',5'-d]pyridazine-ACOT4 complex was observed through root-mean square deviation (RMSD), root mean square fluctuation (RMSF), protein-ligand interaction analysis, and ligand torsion analysis.

RMSD of ACOT4-2,7-diphenyl-1,6-dioxypyridazino [4,5:2',3']pyrrolo [4',5'-d] pyridazine complex

RMSD analysis gives an idea whether the simulation has equilibrated or not, with acceptable fluctuations ranging between 1 to 3 Å. Fig. 5 depicts RMSD plots for simulated ACOT4-2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d] pyridazine complex. As clear from Fig. 5, The C-alpha trajectory underwent initial fluctuations up to 49.90 ns, post which the C-alpha trajectory gained equilibrium until the

end of the simulation period with an overall RMSD of 2.88 Å. Similarly, we analyzed the RMSD trajectory for protein fit ligand complex and found that the trajectory displayed minor fluctuations during initial 13.90 ns, after which the system gained stabilization, from 14.20 ns to the end of the simulation period, with minimum deviations. Overall, the RMSD of protein-fit ligand was found to be 2.17 Å. The lower average RMSD of ligand fit protein complex, when compared with the C-alpha average RMSD points towards the formation of a stable complex.

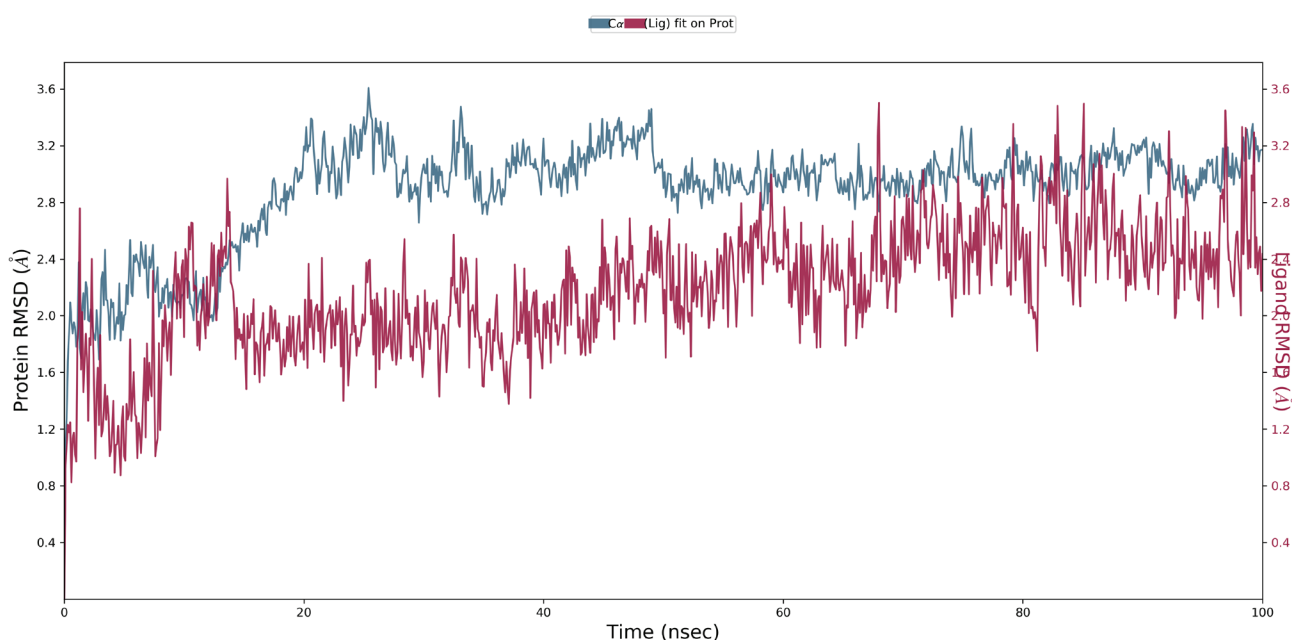


Fig. 5 RMSD Plot of ACOT4-2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine complex

RMSF of ACOT4-2,7-diphenyl-1,6-dioxypyridazino [4,5:2',3']pyrrolo [4',5'-d] pyridazine complex

RMSF is a measure of the displacement of the reference structure over the number of atoms. In Fig. 6, peaks indicate areas of

the protein that fluctuate the most during the simulation. Typically, the tails (N- and C-terminal) fluctuate more than any other part of the protein. Secondary structure elements like alpha helices and beta strands are usually more rigid than the unstructured part of the protein, and thus fluctuate less

than the loop regions. The protein residues that interact with the ligand are marked with green-colored vertical bars. Generally, RMSF value $>2.5 \text{ \AA}$ points towards less stable bonds (Fatriansyah et al., 2022). As shown in Fig. 6, the RMSF plot of C-alpha depicts six peaks,

exceeding the threshold value of $2.5 \text{ \AA}$. These peaks are occupied by SER 106, LYS 237, SER 238, SER, 52, LYS 505 and LYS 237. In addition, the residues responsible for making protein-ligand contacts showed RMSF values within the permissible range, depicting stable bonds.

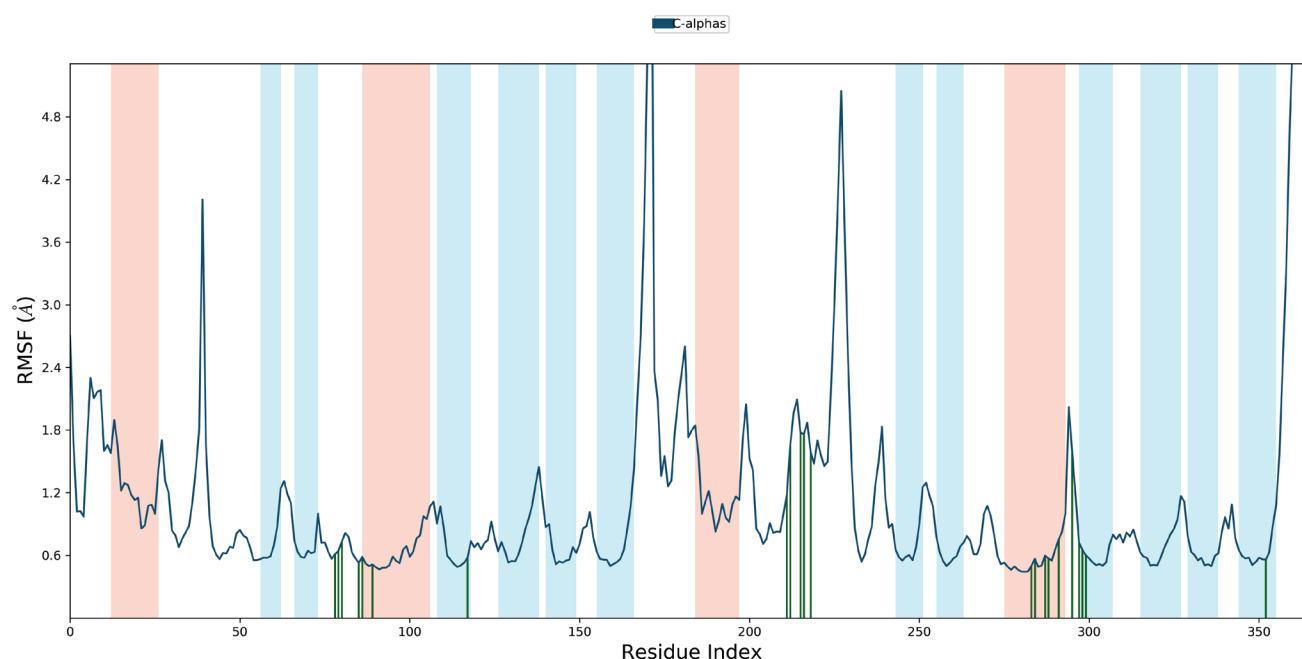


Fig. 6 RMSF Plot of ACOT4 protein

Protein-ligand Contacts

Protein interactions with the ligand can be monitored throughout the simulation. These interactions can be categorized into four types: hydrogen bonds, hydrophobic, ionic and water bridges. Consideration of hydrogen bonds is important due to their strong influence on drug specificity. As shown in Fig. 7, most of the significant ligand-protein interactions

determined with MD are water bridges, hydrogen bonds, ionic and hydrophobic interactions. Four residues participated in the formation of hydrogen bonds i.e. ASP 161, ASP 89, GLY 165 and GLY 152, where ASP 161 showed the highest interaction fraction of 0.998. The protein-ligand interactions maintained for more than 30% of the simulation time are detailed in Fig. 7.

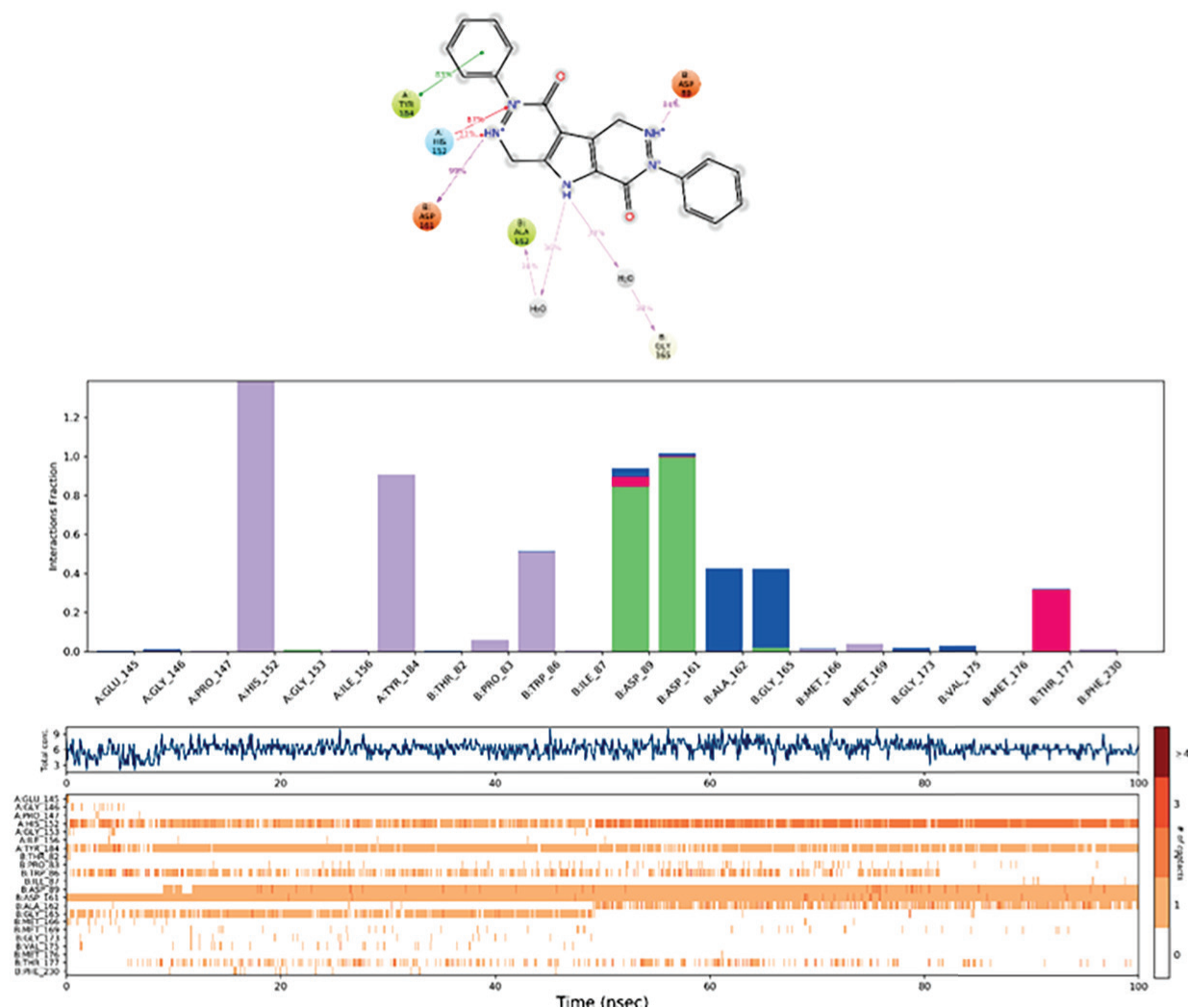


Fig. 7 Protein-Ligand interactions of ACOT4-2,7-Diphenyl-1,6-dioxopyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine complex

Ligand Torsion Analysis

Finally, we analyzed the torsional degree of freedom for the rotatable bonds of 2,7-diphenyl-1,6-dioxopyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine. The compound exhibited two rotatable bonds as shown in a color-coded manner in the ligand torsion analysis figure. Fig. 8 represents dial and bar plots of same color, where the dial plot exhibits the conformation of torsion throughout the

simulation period, starting at the center and evolving radially outwards. In addition, the bar plot briefs the results of dial plots and indicates the probability density of the torsion. In case the torsional potential information is available, it is shown at the y-axis of the bar plot, which may give information about the conformational strain the ligand undergoes to maintain a protein-bound conformation.

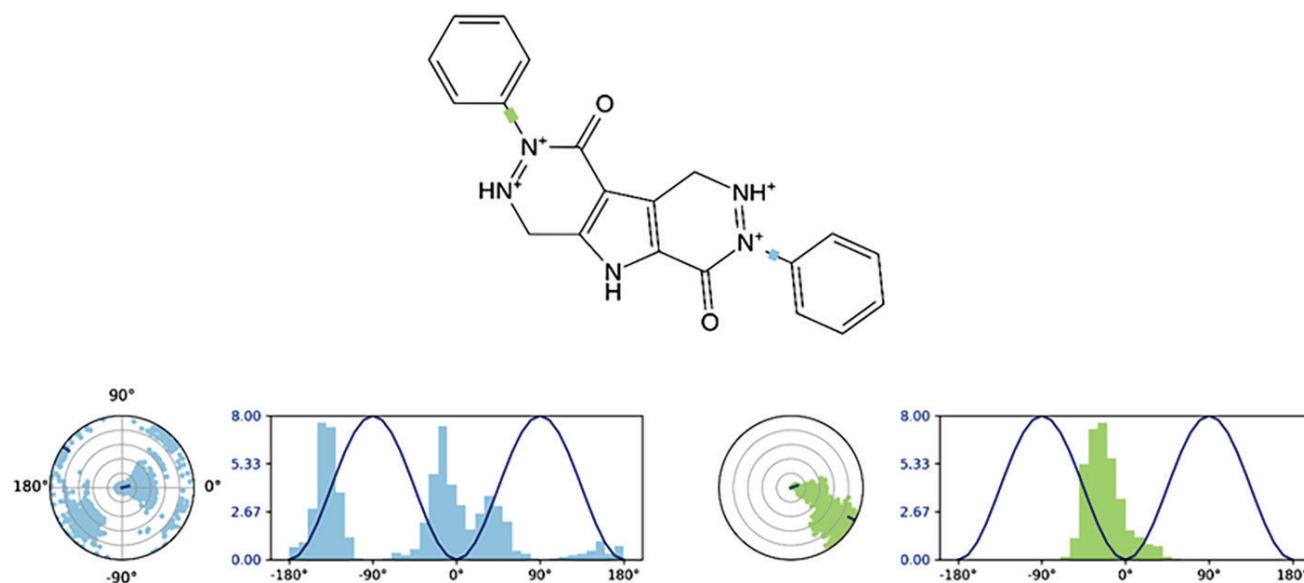


Fig. 8 Ligand torsion analysis of 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine

Conclusion

In conclusion, this comprehensive computational study has unveiled the substantial potential of bioactive phytoconstituents derived from the medicinal plant *R. communis* in targeting the ACOT4 protein. Through the adept utilization of virtual screening, encompassing molecular docking analysis and molecular dynamics simulations, we have provided evidence of the therapeutic promise of 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine in combating GC. Our molecular docking analysis has underscored the robust binding affinity of the compound with the target protein, indicating its potential as an inhibitor for ACOT4 mediated GC. Furthermore, the compound exhibited favorable pharmacokinetic properties, bioavailability, and bioactivities, affirming its safety and suitability as a

prospective drug candidate. The insights gained from molecular dynamics simulations have further substantiated the stability of the ACOT4-2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine complex, shedding light on their potential as an effective therapeutic strategy against GC. In essence, this research has shed light on the promising potential of 2,7-diphenyl-1,6-dioxypyridazino[4,5:2',3']pyrrolo[4',5'-d]pyridazine as a natural therapeutic agent targeting ACOT4, a key protein in the pathogenesis of this viral infection. These findings provide a solid foundation for future investigations and the development of targeted therapies for GC, fostering optimism for improved treatment options and enhanced outcomes for patients afflicted with this disease of concern.

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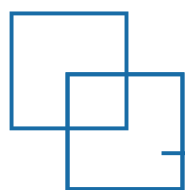
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CHAPTER 07

Reported Pharmacological Profile



INTRODUCTION

Natural product research is a rapidly evolving area with significant global health consequences from its ongoing advancements. The safeguarding of human health depends primarily on medicinal herbs. There are 7,500 species and over 300 genera in the broad family Euphorbiaceae (Oyedemi et al., 2018). The castor oil plant, *Ricinus communis* L., sometimes called “Palma(e) Christi” or “wonder tree,” is a perennial shrub in the Euphorbiaceae family that can heal a wide range of illnesses (Worbs et al., 2011). This tropical plant is widely dispersed all over the world and is also referred to as castor bean (Landoni et al., 2023). India is the natural home of the plant, which is grown in fields and gardens as well as in waste areas. The Romans and Greeks utilized this species, and it is most likely African in origin. These days, the plant may be found almost anywhere in the world as an ornamental plant and thrives wild in many tropical and subtropical locations. The plant, its seeds, and especially its oil have been used historically for several medicinal uses, including as a laxative and to cure inflammation and infections (Worbs et al., 2011).

Pre-Clinical Study

R. communis is a multipurpose folkloric medicinal plant with good medicinal properties; these properties are associated with either direct application of crude plant extract as a therapeutic agent in various diseases or by inhibition of harmful pathogens, which are known to cause various infections and diseases. Among the various reported activities of *R. communis*, many of them are attributed to its extract in crude form followed by various fractions which could be ethanolic, methanolic or chloroform, ethyl acetate, toluene, benzene, and butanol solvents.

Numerous studies have been carried out and published on the biological activities of *R. communis* plants. These activities are both due to the crude extract and its phytochemical compounds which can be of great interest in future for the development of plant-based complementary medicine.

Analgesic Activity

Taur et al. (2011) studied the anti-nociceptive potential of methanol extract (100, 125 and 150 mg/kg b.w.) of *R. communis* leaves



against acetic acid-induced writhing, formalin-induced paw licking and tail immersion methods in albino mice. The extract significantly ($p < 0.001$) reduced acetic acid-induced writhing with approximately 40% when compared with diclofenac sodium (70.2%) used as positive control. In formalin-induced paw licking test, the extract inhibited neurogenic and inflammatory phase, while the extract exhibited an increase in latent time after 90 min. at 150 mg/kg dose for tail immersion test.

Anti-asthmatic Activity

Taur and Patil (2011) reported the anti-asthmatic activity of ethanol extract (100-150 mg/kg, b.w.) of *R. communis* root against milk-induced leukocytosis and eosinophilia, mast cell degranulation's in albino mice as well as, passive cutaneous anaphylaxis in Wistar rats. The extract decreases milk induced leukocytosis and eosinophilia and protected degranulation of mast cells in mice. Also, the extract exhibited significant ($p < 0.001$) reduction in dye leakage from dorsal skin of rats.

Anti-convulsant Activity

Tripathi et al. (2011) performed the anti-convulsant effect of ethanol dried extract and isolated ricinine (60 mg/kg b.w. oral) from *R. communis* seeds using maximal electroshock (MES) model in albino mice. Ricinine significantly ($p < 0.05$) reduced the extensor tonus phase of convulsion in mice when compared with diazepam (30 mg/kg b.w.),

used as standard drug. In addition, ricinine also exert 82.07% inhibition of seizure when compared to diazepam (88.89%).

Anti-diabetic Activity

Li et al. (2014) demonstrated the anti-diabetic activity of 30-norlupan-3 β -ol-20-one and lup-20 (29)-en-3 β ,15 α -diol isolated from methanolic extract of *R. communis* aerial parts against 11 β -hydroxysteroid dehydrogenase (11 β -HSD) enzymes of mouse and human. Both compounds showed good inhibitory effect towards 11 β -HSD of mouse and human.

Anti-fertility Activity

Makonnen et al. (1999) evaluated the anti-fertility effect of seed extract of *R. communis* in female guinea pigs. The extract prolonged oestrus and dioestrus phases while reduced the weight of uterus without any alteration in ovaries.

Anti-inflammatory Activity

Srivastava et al. (2013) studied the anti-inflammatory activity of methanol extract, its n-hexane enriched fraction along with lupeol and erandone isolated from *R. communis* roots (100 mg/kg, b.w.) against carrageenan-induced hind paw edema in rats. Indomethacin (15 mg/kg, p.o.) was used as positive control. The fraction (100 mg/kg) showed relatively significant ($p < 0.001$) effect in systemic paw edema with 26.5% inhibition, followed by extract (15.44%) when compared with indomethacin (58.09 %). Both compounds (100

mg/kg) exhibited weak effects with percentage inhibitions as 7.35 and 8.56%, respectively for tested model.

Ilavarasan et al. (2006) evaluated the anti-inflammatory potential of methanol extract (250 and 500 mg/kg, b.w. p.o.) from *R. communis* roots against carrageenan-induced hind paw edema and cotton pellet granuloma models in albino Wistar rats. The extract at higher dose showed inhibitory effect with 65.78 and 43.66% on paw edema and cotton pellet granuloma, respectively, when compared with diclofenac sodium (71.05 and 50.42%) used as positive control.

Nemudzivhadi and Masoko (2014) reported the anti-inflammatory effect of n-hexane, dichloromethane, acetone, and methanol extracts of *R. communis* leaves using RAW 264.7 macrophage cell lines. The n-hexane, acetone and methanol extracts reduced the level of ROS formation in cells while dichloromethane extract found to be inactive.

Anti-leishmanial Activity

Rondonetal.(2011)studiedtheanti-leishmanial potential of ethyl acetate, chloroform, and methanol extracts of *R. communis* roots against promastigotes and amastigotes of *Leishmania infantum*. Pentamidine and amphotericin B were used as positive controls. All extracts exhibited inhibitory effect with IC₅₀ values ranged from 2.85 to 11.12 µg/ml for *L. infantum* promastigotes when compared with pentamidine (0.17 to 23.11 µg/ml). However, ethyl acetate and chloroform extracts were found most effective with 17.28 and 17.32 µg/

ml, respectively for amastigotes as compared to amphotericin B (0.08 to 51.87 µg/ml).

Anti-malarial Activity

Wachira et al. (2014) reported the anti-malarial activity of methanol extract along with ricinine and 3-carboxy-4-methoxy-N-methyl-2-pyridone isolated from *R. communis* leaves against malaria vector *Anopheles gambiae*. The larvicidal activity of all the extracts increased with the exposure time with the highest mortality recorded for the extract from *R. communis* after 72 h of exposure (LC₅₀ 0.18 mg/mL). Besides, both compounds exhibited long survival time with mean survival of 4.93, 4.50, and 4.85 days, respectively.

Anti-microbial Activity

Leite et al. (2014) evaluated the anti-microbial activity of oil (25 µg/l) from *R. communis* against *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus mutans*, *Enterococcus faecalis*, *Candida albicans* and *C. glabrata* using broth dilution method. The extract exhibited the highest inhibitory effect with MIC value of 195 µg/ml for *S. aureus*, followed by *C. albicans* and *C. glabrata* (781 µg/ml) whereas for other microorganisms, it was found to be ineffective.

Zarai et al. (2012) evaluated the anti-microbial potential of essential oils from leaves of *R. communis* against *Staphylococcus aureus* (1327 and 25923), *Bacillus subtilis*, *B. cereus*, *S. epidermidis*, *Micrococcus luteus*, *Enterococcus faecalis*, *Enterobacter cloacae*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Escherchia*

coli, *Penicillium digitatum*, *Fusarium solani*, *Aspergillus niger*) using agar disc-diffusion method. Ampicillin and cycloheximide (10 µg/disc) were used as positive controls. The oils exhibited inhibitory effect with zone inhibitions ranged from 6.2 to 28.4 mm, while highest inhibition was observed for *B. subtilis* (28.4 mm) followed by *S. aureus* (24 mm), *E. cloacae* (22.6 mm) and *P. aeruginosa* (8 mm) when compared with ampicillin (20 to 26 mm). Moreover, oils attained effectiveness with values ranged from 4.2 to 10.2 mm when compared with cycloheximide (21 to 30 mm) for fungal strains. It was inactive for *A. niger*.

Kota and Manthri (2011) studied the anti-bacterial effect of ethanol extract of *R. communis* leaves against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Proteus vulgaris* and *Pseudomonas aeruginosa* using cup plate method. The extract exhibited zones of inhibition as 13.1, 15.1, 16.3, 16.5 and 19.1 mm as compared to gentamycin used as standard drug (11.6 to 14.1 mm) for tested strains.

Antioxidant Activity

Ravishankar et al. (2015) reported the antioxidant activity of ethanolic leaves extract (100, 200 and 500 µg/ml) of *R. communis* using DPPH and reducing power assays. Gallic acid (1 and 2.5 µg/ml) was used as standard drug. The extract exhibited DPPH effect with IC₅₀ values of 37.32 µg/ml when compared with gallic acid (0.81 µg/ml). In reducing power assay, the extract increased absorbance of 0.947 with an

increase in concentration as compared to gallic acid (0.765).

Ilavarasan et al. (2006) evaluated the antioxidant effect of methanol extract (250 and 500 mg/kg, b.w. p.o.) of roots of *R. communis* using DPPH, nitric oxide, hydroxyl, and lipid peroxidation induced by CCl₄ and ferrous sulphate in rat liver and kidney homogenates. The extract exhibited good inhibitory effect with IC₅₀ values of 12, 181 and 143.30 µg/ml for DPPH, nitric oxide and hydroxyl scavenging methods, respectively, when compared with vitamin C (0.65, 0.67 and 39.21 µg/ml) used as positive control. Moreover, the extract attained effectiveness of 172.65 and 236.28 µg/ml and, 149.85 and 202.29 µg/ml for lipid peroxidation initiated by CCl₄ and Fe₂SO₄-initiated rat liver and kidney homogenates models, respectively.

Abbas et al. (2018) evaluated the antioxidant potential of methanol extracts (by shaking, sonication and Soxhlet extraction methods) from *R. communis* leaves, stem, fruit, roots, and seeds using DPPH, reducing power and linoleic acid oxidation assays. Among tested extracts, the seed extract in case of sonication showed good effect in DPPH, linoleic acid and reducing power method with value of 8.8, 87.28% and 0.854 (OD), followed by Soxhlet (7.42%, 48.19% and 0.523 OD) and, shaking (7.25%, 43.56% and 0.481 OD) whereas, other extracts by different extraction methods exhibited inhibitory effect ranging from 6.2 to 14.33% (DPPH), 6.63 to 57.38% (linoleic acid) and reducing power from 0.194 to 0.578 (OD), respectively.

Nemudzivhadi and Masoko (2014) reported the antioxidant activity of n-hexane, dichloromethane, acetone, and methanol extracts of *R. communis* leaves using ABTS assay. The methanol extract showed highest percentage inhibition of 95% at 2.50 mg/ml, followed by acetone (91%) and dichloromethane (62%), while n-hexane with least effect of 50% for tested assay.

Anti-parasitic Activity

Zahir et al. (2011) reported the anti-parasitic activity of n-hexane, chloroform, ethyl acetate, acetone, and methanol extracts (1,000 ppm) and epicatechin (6.25 to 100 ppm) isolated from *R. communis* leaves against *Paramphistomum cervi*. Among tested extracts, the ethyl acetate and methanol extracts showed highest mortality with 94 and 87% against *P. cervi*. In addition, epicatechin at highest dose also exhibited inhibitory effect with LC₅₀ value of 31.2 ppm for tested parasite.

Anti-tumor Activity

Lin et al. (1986) evaluated the anti-tumor potential of ricins A, B and C isolated from *R. communis* seeds on growth of tumor cells (S-180, LTK-cells, non-transformed 3T3 cells) in ICR mice. The ricin A exhibited potent growth inhibitory effect with ED₅₀ values of 1.0×10^{-10} , 2.6×10^{-10} and 7.8×10^{-10} g/ml for tested cell lines. Also, ricin A improved the percentage life span (62%) of tested mice.

Darmanin et al. (2009) studied the anti-tumor potential of volatile extract from *R. communis* leaves against human skin melanoma (SK-

MEL-28, COLO 679), chronic myeloid leukemia (K-562), breast adenocarcinoma (MCF-7), colon adenocarcinoma (HT-29), ovarian carcinoma (OAW42), Primary peripheral blood mononuclear (PBMC) cell lines by MTT assay. The extract exhibited cytotoxic effect with IC₅₀ values ranging from 10 to 40 µg/ml for tested cell lines. Also, the extract at 20 µg/ml induced apoptosis in SK-MEL-28 cells.

Contraceptive Activity

Nath et al. (2013) evaluated the contraceptive activity of petroleum ether (PE), ethyl acetate (EA), acetone (AC) and lyophilized aqueous (AQ) extracts of *R. communis* stem bark (100, 200 and 300 mg/ml, b.w.) in human sperm sample. AQ showed most potent contraceptive effect with 100% reduction in rapid progressive motility (10 min of incubation) and 91.33% ($p < 0.001$ and $p < 0.05$) sperms became immotile within 30 min of incubation when treated with 100 mg/mL AQ whereas, other extracts exhibited percentage reduction in rapid progressive motility by 49.67, 37 and 27.33% (5 min.) and, 44, 30 and 22% (10 min.) for with PE, EA and AC, respectively. Further, all extracts (300 mg/ml) significantly ($p < 0.001$ and $p < 0.05$) increased hypo-osmotic swelling. Nevertheless, following treatment with three distinct AQ concentrations (100, 200, and 300 mg/mL) (Table 4), a substantially ($p < 0.05$) greater proportion of sperm (91% at the highest dosage concentration) did not decondense at all. However, a gradual reduction of halo formation percentage observed in acrosomal reaction ranging from 79 to 48%.

Cytotoxicity

Rondon et al. (2011) evaluated the cytotoxicity of ethyl acetate, chloroform, and methanol fractions (100 µg/ml) of *R. communis* roots on monocytic lineage cells of murine RAW 264.7 cells by MTT assay. Amongst tested fractions, the ethyl acetate fraction showed maximum cell viability with 83.5% when compared with amphotericin B (90%) used as positive control.

Abbas et al. (2018) evaluated the cytotoxicity of methanol extract (by shaking, sonication and Soxhlet methods) of *R. communis* leaves, stem, fruit, roots, and seeds against red blood cells (RBCs) of human and bovine. In case of shaking, the methanol extract showed cytotoxic effect with percentage inhibitions ranging from 3.51 to 50.9% (human RBCs lysis), 2.23 to 44.91% (bovine RBCs lysis), followed by sonication (0.76 to 15.56%; human RBCs), (0.71 to 13.32%; bovine RBCs) and Soxhlet method with 0.70 to 34.20% and, 0.07 to 41% for human RBCs and bovine RBCs lysis, respectively.

Nemudzivhadi and Masoko (2014) reported the cytotoxicity of n-hexane, dichloromethane, acetone, and methanol extracts of *R. communis* leaves on human Caucasian skin fibroblast (Bud-8) cell line using MTT assay. All extracts showed cytotoxic effect with LC_{50} values ranging from 387.1 to 495 µg/ml for tested cell line.

Effects on Reproductive System

Raji et al. (2006) studied the effectiveness of methanol extract of *R. communis* seeds (20

and 40 mg/kg/d) on reproduction of male albino rats. The extract did not affect normal increase in body weight of rats. Similarly, there was no significant difference ($p > 0.05$) observed in mean weight of the heart, kidney, and liver in the RCE-treated groups, while a significant ($p > 0.05$) reduction in mean weight of testis, epididymis, prostate gland, and seminal vesicle when compared with control group. There was a significant decrease ($p < 0.01$) in sperm count, motility, viability as well as, number of normal spermatozoa, serum levels of testosterone. The number and weight of litters of rats with dose 20 mg/kg RCE decreased significantly ($P < 0.05$) but no changes were observed in recovery group (40 mg/kg RCE, recovery) when compared with vehicle treated control group. Lastly, the histopathological studies revealed that there was disorganization in the cytoarchitecture of testes, disruption of seminiferous tubules and erosion of germinal epithelium.

Enzyme Inhibitory Activity

Zhang et al. (2018) assessed that 3 α ,19-dihydroxyl-ent-pimara-8(14),15-diene obtained from rhizomes of *R. communis* was studied for inhibitory activity against protein tyrosine phosphatase 1B (PTP1B) enzyme. The compound at 20 µg/ml inhibited PTP1B by 49.49% in comparison with oleanolic acid (1.18 µg/ml) used as positive control.

Hemagglutinating Activity

Lin et al. (1986) evaluated the hemagglutination activity of ricins A, B, and C and ricinus

agglutinin isolated from *R. communis* seeds on red blood and S-180 cells. Among these compounds, ricinus agglutinin showed a greater ability (1.56 and 6 µg/ml) to agglutinate both red blood and S-180 cells, than ricins A (200 and 22 µg/ml), B (145 and 62 µg/ml) and C (50 and 25 µg/ml), respectively. Further, ricin C attained highest ability to agglutinate red blood cells, while all three had similar abilities to aggregate S-180 cells.

Hepatoprotective Activity

Babu et al. (2017) demonstrated the hepatoprotective activity of methanol extract of *R. communis* leaves against D-galactosamine (D-GalN)-induced hepatitis rat model. The extract altered enzymatic activities such as GSH and MDA to normal levels. Histopathological examination revealed that the extract showed protective and curative effects towards D-GalN intoxication in the rat liver.

Mutagenicity

Abbas et al. (2018) evaluated the mutagenicity of methanol extracts (by shaking, sonication

and Soxhlet) of *R. communis* leaves, stem, fruit, roots, and seeds against TA98 and TA100 strains of *Salmonella typhimurium*. The extracts showed mild mutagenicity ranged from 1975 to 2628 and, 2773 to 3461 revertant colonies for both tested strains as compared to dimethyl sulfoxide (3267 and 4720 at 0.25 and 0.5 µg/plate, respectively) used as positive control.

Anti-spermatogenic Activity

Nithya et al. (2011) evaluated the spermatogenic activity of 62 kDa protein (Rp; 25 mg/kg, b.w./d) isolated from *R. communis* root in Swiss mice. Rp at tested dose reduced the fertility index (100%) and sperm count when compared with control group. Besides, the testicular activities of glucose 6-phosphate dehydrogenase, malic enzyme, level of serum testosterone and expression of 3HSD and 17HSD were reduced in treated mice, while the expression of StAR increased by Rp when compared to the control group. In addition, Rp did not cause any changes in the histology of testes, but the number of spermatozoa was decreased in mice.

Toxicological Study

Ilavarasan et al. (2011) studied the acute and sub-acute toxicity of aqueous and methanol extracts (1000 and 2000 mg/kg, b.w.) of *R. communis* roots in albino Wistar rats. In acute oral toxicity, both extracts (2000 mg/kg, b.w.) did not produce any toxic symptoms

or mortality in rats. While repeated dose of both extracts (1000 mg/kg) demonstrated no significant changes in body weight, food, and water intake after 90 days of administration. Moreover, the hematological parameters such as white blood cells, red blood cells,

hemoglobin, clotting time, and differential leukocyte count did not produce any significant changes when compared with control group. Similarly, no significant changes found in the biochemical parameters like total serum protein, alkaline phosphates, blood urea nitrogen, creatinine, AST, ALT, cholesterol, glucose, and total bilirubin parameters as well as, no detrimental and morphological alterations were observed when administered

with both extracts compared to control animals.

Abbas et al. (2018) reported the brine shrimp lethality test of methanol extracts (by shaking, sonication and Soxhlet) of *R. communis* leaves, stem, fruit, roots, and seeds against *Artemia salina* nauplii. The extract exhibited toxic effect with LC₅₀ values ranging from 0.22 to 3.70 µg/ml (shaking), 1.59 to 60.92 µg/ml (sonication) and 0.72 to 33.60 µg/ml (Soxhlet), respectively.

Summary And Future Outlook

R. communis is one of the medicinal plants which have multiple pharmacological applications against various diseases and disorders. The anti-tumor, anti-diabetic, anti-malarial and anti-microbial activities of this plant are the shaft of light in treating the death-causing diseases throughout the world. The various biological activity of this species is due to the presence of a varied degree of bioactive phytochemicals. Through this chapter, it can be justified that both crude form

of plant extract and the isolated compounds are responsible for its pharmacological and therapeutic potential. Further studies and utilization of these plant compounds in an isolated form can be performed to explore their mechanism of action and by deciphering the actual process by which these plant phytochemicals reach the target and exert their action. Novel drugs can be designed by performing various *in vitro* and animal studies of these phytoconstituents.

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