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RESEARCH ARTICLE

Concept development and rula analyis of a virtual prototype wheelchair for physically challenged persons

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ABSTRACT

A wheelchair is one of the common internal locomotive vehicles used by handicap or sick people who are limited in their functions, such as it needs human force to move it and carry the person from a bed to a wheelchair. This study aims to design and develop a wheel chair using concept generation, concept design, and selection of a concept using different selection methods. Various designs of different parts in a wheelchair have been generated and suitable designs are combined to generate concepts. The Pugh chart and weighted decision matrix have been used to select the best concept based on the criteria. The selected concept has been modeled and analyzed using CATIA RULA module. Human comfort has been analyzed using RULA analysis. It was identified that current virtual prototype developed is safe and comfortable for the caretaker and patient.

Keywords: Conceptual design, Morphological chart, Pugh chart, RULA analysis

1. INTRODUCTION

Product development focuses on current and market opportunities by evolving customer requirements. The process model is the central component of the product model. The product development has different phases.

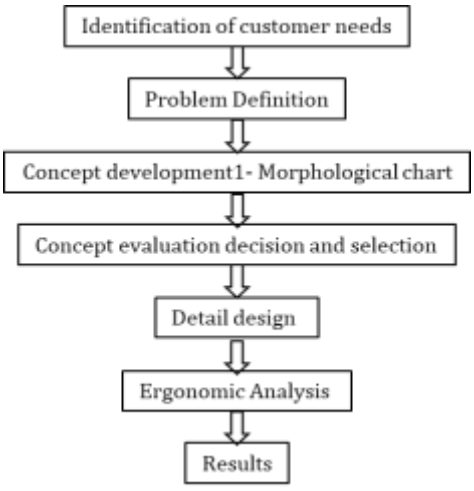

Figure 1. Detailed methodology

The first phase identification of customer needs truly indicates the customer problems; it can be identified in several ways like conducting focus group, survey. Focus group is a method employed to identify the needs of selective number of physically challenged person's. A group of ten physically challenged persons and their responses to the facilitator questions on the proposed problem is recorded. The next phase is problem definition; the detailed statement of the problem is developed. The concept development is used to generate a concept for the problem and the concepts were evaluated using a Pugh chart and weighted decision matrix. The final concept is generated based on the score. Detailed design and virtual prototype development for RULA analysis is proposed for caretaker and patient safety. Jyoti Pragyan Satpathy [1] analyzed and developed a prototype of a motorized wheelchair based on market survey, customer requirements. The project starts with initial research, literature review, and background study. The next phase is concept generation with outlining specifications and a rough sketch. The next phase is design, modeled by using CATIA. The fourth phase is the detailed design phase and the final phase is prototyping and tests the model. Arunachalam et al [2] identified a customer product like a bicycle and developed different concepts using the concept generation method and evaluated the concepts using Pugh chart and numerical scoring methods. Ashby method was selected for material selection. This study checked the human comfort like knee

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clearance, hand reach, foot reach of the bicycle, and FEA analysis under static and dynamic loading for safety. Sreerag et al [3] reported the various issues of mobility equipment and introduced a better design for helping disabled peoples. The wheelchair facilitated the patients and provides equipment for hospitals. Various research methods about hospital mobility aids and data have been collected. QFD was generated and the main priority was given to mechanism, safety, ergonomics, and functionality. Kedar Sukerkar [4] identified the issues faced by the manufacturers and researchers for the wheelchair. One of the major issues is cost versus accuracy. Smart wheelchair for all types of disability is still not available and it should have the ability to monitor the patient conditions. It can be easily used indoor, but for outdoors it needs supervision. Smart wheelchairs have a great scope in the field of robotics and sensors will lead to success. Anjeneyulu & Purushotham [5] understood the issues of disabled people and paid more attention. The stair climbing wheel can work in three modes: stair-climbing mode, powered wheelchair mode, and manual mode. The walking mechanism was first designed, as well as theoretical design and calculation was formulated for the structure and dimensions. The seat backrest adjustment and locking system were installed to make the product safer. Finally, stress analysis, material selection, and animation were made the wheelchair works in a different situation.

Rajasekar et al [6] designed a manually operated wheel chair that can travel on both plain terrains and staircases also. At the time of climbing, one wheel will be in contact with the ground and another wheel will be in contact with the stair. The cost of the stair climbing wheelchair and the normal wheel chair was high when compared to the designed wheel chair. Thus, can be best suited for middle class people. S Chatterjee and S Roy [7] developed a low cost mixed control wheel chair controlled by joystick or Voice. Mixed control wheelchair is presented for paralyzed and elderly people.MCW is the main control to provide appropriate actions. Sree Amrutha Valli Kuppa et al [8] proposed a wheel chair for specially disabled for daily usage. The joystick module, blue tooth module, voice control and android app knowledge helped the handicapped people perform the day to day activities unaccompanied by anyone.

2. PROBLEM DEFINITION

The literature survey showed that wheel chair design for the disabled person lifting from bed and moving to washroom is not addressed. The wheelchair is available in the market, which is limited in its function. The available wheelchair is not easily foldable, tough to remove the seats and backrest. A caretaker is needed to take the disabled people from bed to wheelchair. The disabled person couldn't use the wheelchair while moving to the washroom. This leads to the requirement of designing a product which is easily foldable, adjustable seat and backrest and also easily carry the disabled people from bed.

3. CONCEPTUAL DESIGN

Conceptual design is the early stage of the design phase and comes out with several concepts and it is immediately followed by the schematic design phase. It also involves an understanding of people's needs.

3.1. Concept Generation

The concept development phase moves into the concept generation. The main aim of this phase is to generate several concepts based on components used in Wheelchair.

The morphological chart is one of the tools used for concept generation. After the concept development, the component for each concept was selected. Different concepts have been generated from the morphological chart as shown in Figure 2.

The morphological charts are developed based on the below points.

1. For each component in the wheel chair a number of solutions is listed.

2. Repeat the same for all the components proposed to be used in the wheel chair.

3. Mark the solutions for each concept and draw the combinations.

Based on the above three steps, various concepts have been evolved from the morphological chart are shown in Figures 3 – 6.

Components	Datum	1	2	3	4
Seat	0	Square	Rectangle	Half round	Ellipsoidal
Wheel	0	Stair climbing wheel	Single wheel	6 wheels roller moving wheel	4 wheels roller moving wheel
Arm rest	0	"T" shape	"L" shape	"J" shape	"U" shape
Back rest	0	Square	Trapezoidal	Round	Ellipsoidal
Lock	0	Strap	Lifting type hook	Lifting type hook	Lifting type hook
Foot Rest	0	Foldable foot rest	Rectangular in shape	Rectangular in shape	Foldable foot rest
Back legs of wheelchair	0	"H" shape	"L" shape	"L" shape	Circular rod

Figure 2. Morphological chart

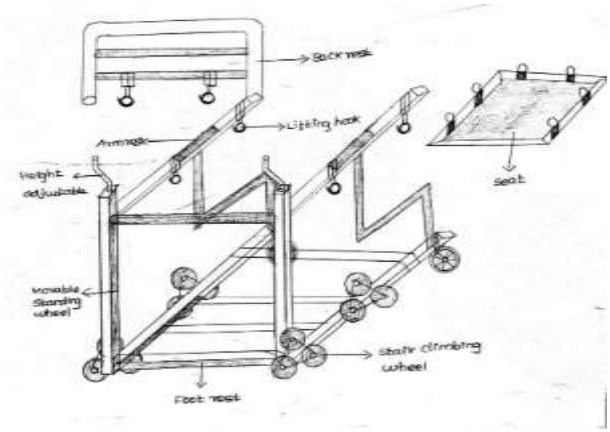

Figure 3. Concept 1 a2-b1-b2-c2-d1-e2-f3-g1

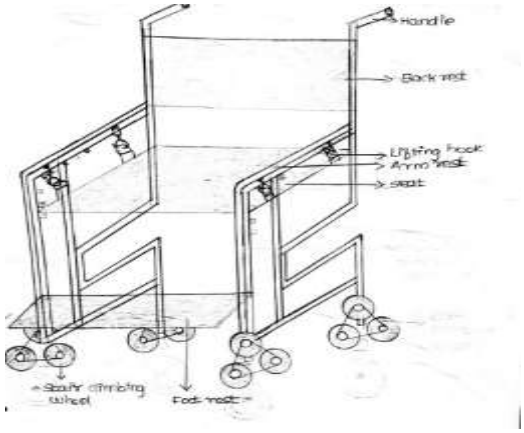

Figure 4. Concept 2 a2-b1-c2-d1-e2-f2-g1

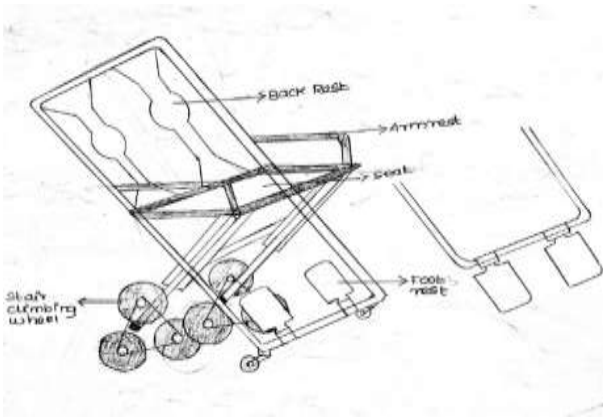

Figure 5. Concept 3 a2-b1-b2-c2-d1-e3-f1-g4

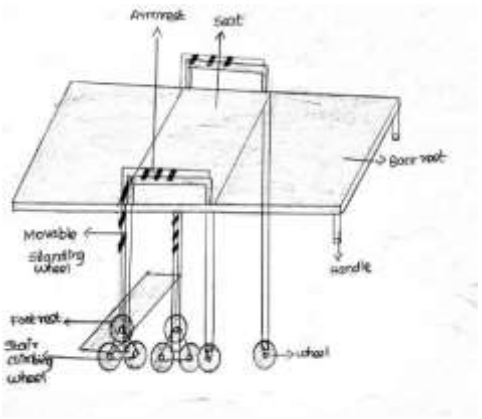

Figure 6. Concept 4 a2-b1-b2-c4-d1-e2-f2-g4

3.2 Concept Evaluation and Selection

The next step of conceptual design is concept evaluation. There are number of methods available to refine the concepts. The Pugh chart and weighted decision matrix are the two methods are used during concept selection. The first step of concept evaluation is to set a criteria's on which the concepts are selected.

3.2.1 Pugh chart

Table 1 shows Pugh chart for the product wheel chair. The criteria are formed based on the features of the product. The concepts are evaluated based on the symbols (-, 0, +) where '-' is worse than datum '0' is same as datum, '+'is better than datum. The criterion is performed better than datum than the concept assigned as '+' sign. If it's performed worse than datum then the concept assigned as'-' sign. If the performance of the criteria is same as the datum then assigned it as '0' sign. The net score for each concept is based on the sign and it decides the concepts going to next level.

Table 1. Pugh concept selection chart

CRITERIA'S	DATUM	CONCEPT 1	CONCEPT2	CONCEPT 3	CONCEPT4
Ability to transfer handicap to bed	0	+	+	0	+
Easily fit to bed	0	+	+	0	+
Backrest adjustability	0	0	0	-	+
Safety handle handicap	0	+	+	0	0
Easy maintenance	0	-	-	+	0
Easy foldability	0	0	-	+	-
Easy use of lifting hooks	0	+	+	-	-
Ability to withstand the force in back legs	0	-	-	0	0
Customize seat design	0	0	0	-	-
Easy detaching of wheels	0	+	+	-	+

Sum +'s	0	5	5	2	4
Sum 0's	0	3	4	4	3
Sum –'s	0	2	3	4	3
Net score	0	3	2	-2	1

3.2.2 Weighted decision matrix

The weighted decision matrix assumes all criteria having the same importance. The weighted scale can be scaled in percentage and the score of each item on a scale is between 1 (poor) to 5 (very good). Finally add up all the weights for each concepts. The highest score was selected for further level. Table 2 shows the weighted decision matrix of wheel chair.

Table 2. Weighted decision matrix

CRITERIA'S	WEIGHTS	CONCEPT 1		CONCEPT 2	
		SCORE	TOTAL	SCORE	TOTAL
Ability to transfer handicap to bed	12%	5	0.6	5	0.6
Easily fit to bed	12%	5	0.6	4	0.48
Backrest adjustability	8%	4	0.32	3	0.24
Safety handle handicap	9%	4	0.36	3	0.27
Easy maintenance	6%	3	0.18	2	0.12
Easy foldability	8%	2	0.16	3	0.24
Easy use of lifting hooks	11%	4	0.44	3	0.33
Ability to withstand the force in back legs	12%	3	0.36	3	0.36
Customize seat design	10%	4	0.4	3	0.3
Easy detaching of wheels	12%	4	0.48	4	0.48
Total	**100%**		**3.9**		**3.42**

4. EMBODIMENT DESIGN

Embodiment design is a part of design process and it has various stages to carryout ideas. The stages are CAD model human comfort, check, two-handed chart. All the stages are mentioned below.

4.1 CAD model

Figure 7. RULA analysis

In CAD modeling, the each part of the product were modeled and assembled by using CATIA software

5. RULA ANALYSIS IN CATIA V5.

Rapid Upper Limb Assessment (RULA) is used to analyze the upper extremity ergonomic risk factors. The RULA checks the postural load and bio-mechanical requirements for the neck, trunk, and upper extremities. The RULA assessment sheet is a single page worksheet, used to assess the force, posture, and repetitions of work. In RULA worksheet, section A assesses arms, wrists and section B assess of the neck and trunk. The score for sections A & B is totaled to assess the risk of MSD. RULA analysis by mere observation, the results could slightly vary from person to person.

In Catia V5, the manikin posture is developed at sitting and standing posture .The caretaker is in a stand position and physically challenged in a seated position in the wheel chair. Sitting and standing posture of Manikin is selected by an option in the product. Indian Male Anthropometric dimensions of 5th, 50th, 95th Percentile are utilized in the analysis are shown in table 3.

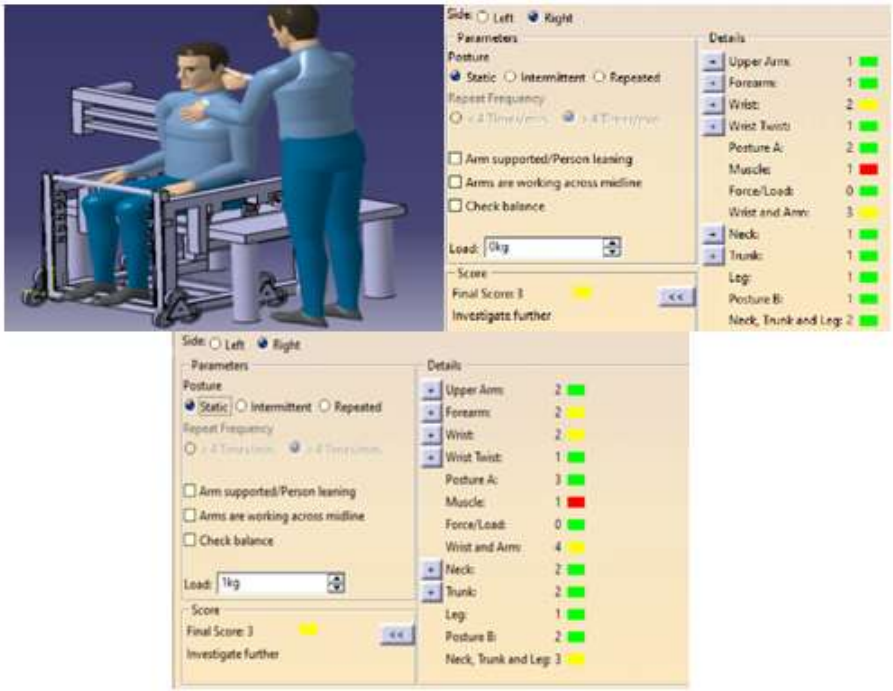

Figure 8. RULA analysis

Table 3. Percentile used

HUMAN COMFORT	INDIAN ANTHROPOMETRIC PERCENTILE USED
Care taker	5^{th}, 50^{th}, 95^{th} p
Handicap	5^{th}, 50^{th}, 95^{th} p

Table 4. RULA score

HUMAN COMFORT	INDIAN ANTHROPOMETRIC 95^{TH}PERCENTILE SCORE	INDIAN ANTHROPOMETRIC 95^{TH} PERCENTILE SCORE	INDIAN ANTHROPOMETRIC 95^{TH}PERCENTILE SCORE
Care taker	3	3	3
Handicap	3	3	3

As the product goes to the next step the RULA tool is used to check the human comfort like care taker and handicap position while using the product. RULA score for the care taker and Handicap are displayed in the table 4.The musculoskeletal disorder risk of 3 is found to be minimum and change of initial design is not required.

6. CONCLUSION

In this paper, a novel design of wheelchair for physically challenged person is discussed. Indian Anthropometric data for Care taker and Handicap for wheelchair using Human Digital Model is deduced. RULA Analysis is conducted to measure discomforts. The virtual prototype checked for caretaker and handicap posture risk indicated a minimum value of 3.It is found to be safe for the caretaker and handicap.

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Conflict of Interest

Author has no conflict of interest.

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REVIEW ARTICLE

Exploring rainfall prediction through regression models: A systematic literature review

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ABSTRACT

This study aims to develop a comprehensive rainfall forecasting system by employing advanced regression models such as CatBoost, XGBoost, Random Forest, SVM, Decision Tree, among others. The primary objectives include identifying, gathering, and preprocessing meteorological and environmental data that influence rainfall patterns. Integration of state-of-the-art regression models is intended to enhance the accuracy of rainfall predictions. The evaluation of these models involves rigorous assessment using performance metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and R-squared. Additionally, a user-friendly interface is designed to facilitate the input of meteorological data, benefiting a wide range of users, including meteorological experts and the general public. The applicability of the system spans across various domains, including agriculture, water resource management, and disaster preparedness.

Keywords: Provide Rainfall prediction, Regression model, Meteorological data, Hyperparameter tuning, Regression analysis

1. INTRODUCTION

Accurate rainfall prediction is indispensable across various sectors, including agriculture, disaster management, and water resource planning. This research paper is dedicated to enhancing the precision of rainfall forecasts through the utilization of robust machine learning techniques, including CatBoost, XGBoost, Random Forest, Logistic Regression, and Support Vector Classifier. These models will be refined and integrated into a user-friendly interface, empowering stakeholders to leverage predictions for informed decision-making.

This initiative responds to the increasing demand for precise meteorological forecasts, particularly in regions where agriculture is economically pivotal, and rainfall variations carry significant socio-economic consequences. By harnessing established and interpretable regression models, our aim is to advance the accuracy of rainfall pattern forecasts, ultimately contributing to the mitigation of uncertainties in weather conditions.

Rainfall prediction presents a formidable challenge in climate forecasting. Machine learning techniques offer a means of unveiling hidden patterns within recorded weather data to forecast rainfall. Such predictions rely on weather-related parameters like temperature, pressure, humidity, and wind speed. Temperature, notably, holds immense importance across various applications, including environmental considerations, manufacturing processes, agriculture, and energy management.

Given that precipitation, wind speed, temperature, and humidity are numerical data, regression analysis will facilitate rainfall prediction. Regression analysis, a statistical method used to establish relationships between independent and dependent variables, is well-suited for forecasting and prediction tasks.

While traditional methods in rainfall prediction have predominantly relied on statistical techniques to examine relationships among geographical coordinates, precipitation, and atmospheric parameters such as humidity, pressure, wind speed, and temperature, the intricate and non-

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linear nature of rainfall patterns has posed formidable obstacles to achieving precise forecasts. Consequently, efforts have been made to address and mitigate this non-linearity by employing methodologies like Empirical Mode Decomposition, Wavelet analysis, and Singular Spectrum Analysis.

Accurate rainfall predictions can raise public awareness about potential risks associated with heavy rainfall, enabling communities to better prepare with emergency kits, evacuation plans, and staying updated on weather forecasts. Water resource management authorities can optimize water allocation for irrigation and domestic use, enhancing the efficient utilization of water resources, particularly in areas with water scarcity.

2. LITERATURE SURVEY

Rainfall prediction system based on machine learning techniques, specifically utilizing 'SoftMax' or multinomial logistic regression. The objective is to predict rainfall categories, wind speed, and temperature using historical weather data from eleven cities in Myanmar. The system categorizes rainfall into one of five classes: Light Rainfall (LR), Moderate Rainfall (MR), Heavy Rainfall (HR), Violet Rainfall (VR), and No Rain (NR). Weather forecasts are essential for society and sustainable development, especially for farmers to optimize agricultural activities.

The system's performance is evaluated using various metrics, including accuracy, precision, recall, F-measure, mean absolute error (MAE), and root mean squared error (RMSE). The system is tested on a dataset containing 1826 days (from 2018 to 2022) for eleven cities. The results show an average accuracy of 83%, with varying performance for different rainfall categories. MAE and RMSE values are also reported to assess the error in predictions. Rainfall prediction is crucial for various applications, and the paper proposes a machine learning-based system for this purpose. 'SoftMax' logistic regression is used to predict rainfall categories based on historical weather data. The system achieves an accuracy of 83% in the experimental results. Future work may involve further improving the system and comparing it with other machine learning techniques [1].

The Research focuses on the development of a rainfall forecasting model for the Jimma region in southwest Oromia, Ethiopia. Rainfall is a critical factor for managing reservoir water levels, especially in agriculture. The experimental results demonstrate the superiority of the proposed approach over various baseline models, including LSTM, bidirectional LSTM (BiLSTM), gated recurrent unit (GRU), and convolutional LSTM (ConvLSTM). The proposed approach achieves the best performance in terms of RMSE and R2, confirming its effectiveness in rainfall prediction. Statistical analyses, such as one-way analysis of variance (ANOVA) and the Wilcoxon signed-rank test, support the significance and stability of the proposed approach. The research contributes to deep learning approaches for rainfall forecasting, offering valuable insights for applications like smart farming. The study's dataset spans several decades and is drawn from Jimma, Ethiopia, with a focus on meteorological parameters [2].

The systematic literature review (SLR) on rainfall prediction, which is a challenging task in weather forecasting with significant implications for various sectors. Accurate and timely rainfall prediction is crucial for activities such as construction projects, transportation, agriculture, flight operations, and flood management. The study aims to provide a critical analysis and review of data mining techniques used for rainfall prediction, with a specific focus on papers published from 2013 to 2017. The research process is systematically outlined, starting with the identification of research questions. These questions serve as the basis for the SLR, aiming to find answers through a critical review. The questions span various aspects of rainfall prediction, including the techniques used, performance evaluation, data types, geographical locations, factors affecting results, and the latest trends in the domain. The study acknowledges its limitations, including the possibility of missing relevant work and the potential for authors' evaluations to introduce bias.

Despite these limitations, the systematic literature review provides a comprehensive overview of the state of rainfall prediction using data mining techniques from 2013 to 2017 and highlights the need for continued enhancements and optimizations in this domain [3]. The use of short-term rainfall data for rainwater harvesting system (RHS) modeling and the identification of representative time series lengths (RTSL) in 12 cities across various climatic zones. RHS has gained importance in mitigating urban water scarcity and flooding issues, making accurate modeling crucial. Short-term rainfall data with inadequate lengths can introduce significant errors in RHS modeling.

The study reveals that RTSL is not significantly correlated with mean annual rainfall or seasonality index but is significantly correlated with

the variation coefficients of annual rainfall. The partial correlation coefficient between RTSL and the variation coefficients of annual rainfall is strong (0.878), while the partial correlation coefficients between RTSL and mean annual rainfall and seasonality index are negative (-0.569 and -0.522, respectively). These findings demonstrate the feasibility of using short-term rainfall data with sufficient length instead of long-term data for RHS modeling, offering valuable insights into the variability of RTSL in diverse climatic zones [4].

"Rainfall Prediction: Accuracy Enhancement Using Machine Learning and Forecasting Techniques" focuses on providing insights into climate and its significance for various businesses, particularly agriculture. It highlights the importance of predicting meteorological parameters, with a specific focus on precipitation. The accuracy of various forecasting models is assessed by comparing the results with ground truth data. Rainfall prediction is crucial for agriculture in India, which heavily relies on precipitation as a water source. It references various studies related to rainfall prediction using machine learning techniques. K. Chowdari's work analyzes monthly climatic changes and seasonal rainfall variability using data from the Indian Meteorological Department and rain gauge stations. L. Ingsrisawang conducts a comparative study on rainfall prediction in the northeastern part of Thailand using different machine learning techniques, such as ANN, SVM, and KNN, with input parameters like temperature, humidity, pressure, and wind speed.

S.N. Kohail uses historical data for the Gaza city to predict and classify temperature, considering attributes like relative humidity, wind speed, and rainfall. Another study by Petre in 2008 uses decision tree algorithms for weather prediction using meteorological data from Hong Kong. In summary, it provides a comprehensive review of various studies related to rainfall prediction and proposes a fusion model for improved accuracy in rainfall forecasting. It emphasizes the importance of understanding the relationships between meteorological parameters and rainfall for more accurate predictions [5].

The study conducted an investigation into rainfall prediction in Lahore city using various data mining techniques. Rainfall prediction is vital for various applications, and given the challenges posed by climate variations, accurate forecasting is crucial. The research aimed to explore the effectiveness of different data mining techniques in predicting rainfall in Lahore city. The techniques employed in the study included Support Vector Machine (SVM), Naïve Bayes (NB), k Nearest Neighbor (kNN), Decision Tree (J48), and Multilayer Perceptron (MLP).

The findings presented in this study demonstrate that data mining techniques, when applied to the task of rainfall prediction in Lahore city, performed well for the "no-rain" class. However, their performance was notably lower when predicting the "rain" class. F-measure, which provides an average of precision and recall, is used as a key accuracy measure in this research. The limitations and potential reasons for lower performance in predicting the "rain" class were explored. This study underscores the significance of accounting for local climatic characteristics and data quality in improving the accuracy of rainfall prediction models, especially in areas with variable and the limited rainfall patterns [6].

3. MATERIALS AND METHODS

The system architecture for a Rainfall Prediction system using regression algorithms comprises several interconnected components that collaborate to deliver accurate predictions. This architecture is designed to integrate data collection, preprocessing, model training, user interaction, and prediction visualization, ensuring reliable and [10] timely rainfall forecasts for diverse applications. The system is engineered to be flexible, scalable, and maintainable to address real-world requirements effectively.

The system commences by aggregating extensive meteorological data from diverse sources, including weather stations, satellites, and remote [7] sensors. This data encompasses crucial variables such as temperature, humidity, wind speed, and atmospheric pressure. Prior to inputting the data into regression models, a preprocessing module undertakes data cleansing and standardization to enhance its quality and consistency. The system architecture is depicted in Fig 1. At the core of the architecture lies a collection of regression models, including Random Forest, XGBoost, CatBoost, and others. Each model is tasked with learning intricate patterns and relationships within the preprocessed [15] data. Leveraging historical [9] weather data, these models are trained to make predictions concerning future rainfall patterns. Ensemble [8] techniques may also be employed to amalgamate the outputs of multiple models, thereby bolstering prediction accuracy.

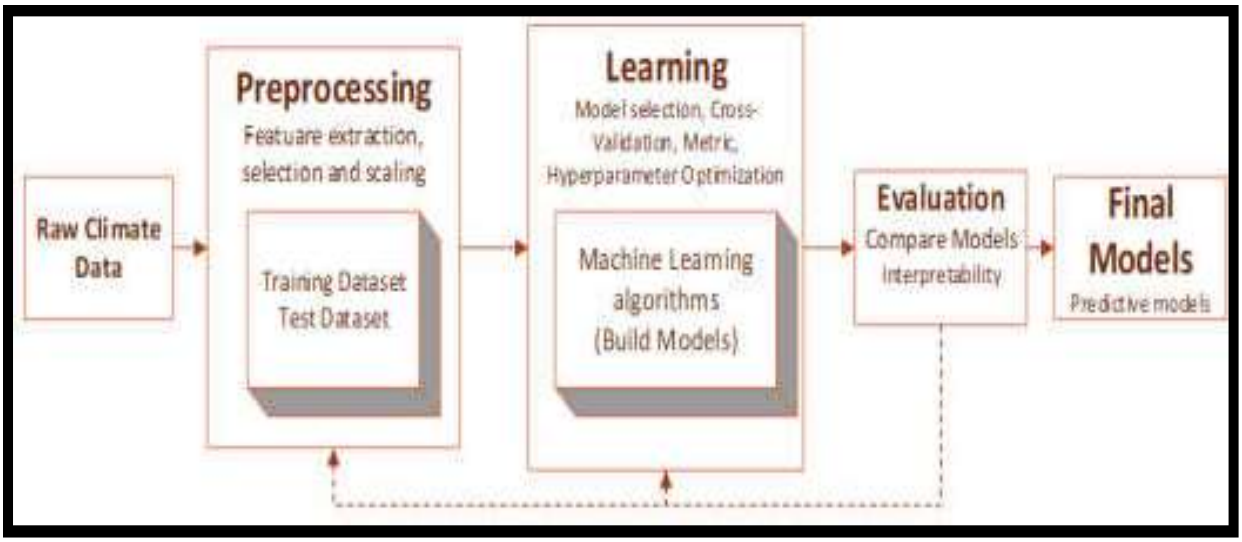

Figure 1. System Architecture

The system employs robust evaluation metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE) [14], and R-squared to gauge the efficacy [13] of the regression models. These metrics facilitate a comprehensive assessment of the models' performance, aiding in the refinement and optimization of prediction outcomes. The different kinds of input data used by the models to make predictions about rainfall, can be used to categorise the various kinds of rainfall forecasting studies. Input data used consideration are depicted in Fig. 2.

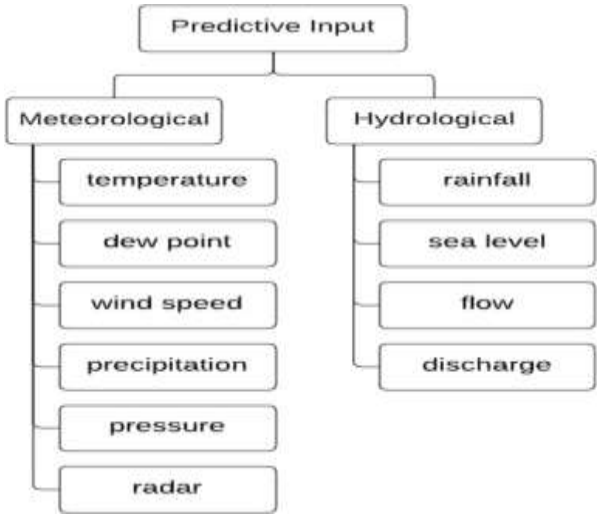

Figure 2. Types of predictive parameters.

Additionally, the system incorporates user interaction [12] features, enabling stakeholders to input specific parameters or preferences and visualize prediction results through intuitive interfaces. This interactive aspect enhances user engagement and facilitates informed decision-making across various sectors reliant on rainfall forecasts.

4. CONCLUSION

In conclusion, this research paper focuses on the development of a comprehensive rainfall prediction system that leverages advanced regression models, including CatBoost, XGBoost, Random Forest, SVM, Decision Tree, among others. The primary objectives of this project include the identification, acquisition, and preprocessing of meteorological and environmental data influencing rainfall patterns. By incorporating state-of-the-art regression models, the research aims to significantly enhance the accuracy of rainfall predictions.

The evaluation of these models employs well-established performance metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and R-squared. Moreover, the research emphasizes the importance of making this system easily accessible through a user-friendly interface, benefiting a diverse user base, including meteorological experts and the general public. The application of this system spans across various domains, such as agriculture, water resource management, and disaster preparedness. The literature survey within this research paper highlights the significance of accurate rainfall predictions for various sectors and demonstrates the value of machine learning and data mining techniques in addressing the challenges of forecasting rainfall. The integration of regression algorithms, coupled with the outlined system architecture, offers a promising approach to address the complexities of rainfall prediction and contribute to informed decision-making across a range of applications.

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RESEARCH ARTICLE

Impact of chemical stress on secondary metabolites of *BACOPA MONNIERI* (L.) WETTST

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ABSTRACT

The demand for cultivating medicinally important plants has a lot of scope and significance at present and in the near future. The present study has been carried out to check the impact of chemical stress on secondary metabolites in medicinally important plant *Bacopa monnieri* (L.) Wettst. As the initial step the plant was cultivated in optimum environment conditions. They were subjected to stress by applying chemicals such as urea and salt in separate pots in different doses. The urea and salt stress has induced several biochemical changes that lead to morphological changes. The morphological observations showed presence of yellow colour in leaves. But there were no any serious effects observed in plant life. After stress application plants were collected separately and it was shade dried, powdered and stored separately. Using the powdered sample and ethanol extract of the plant the total phenolic contents, flavonoids, terpenoids, alkaloids and saponins were evaluated and compared the control and plants subjected to stress. Higher the stress gives higher content of secondary metabolites except the few. The study proves that there is production of secondary metabolites during stress conditions in the plant *Bacopa monnieri*. The production is higher in such treated plants when compared to plants kept as control. This piece of research has paved a way for its improved commercial production. Further the researchers can also proceed with other research analysis based on compounds synthesized through application of different stresses to this plant.

Keywords: *Bacopa monnieri,* Secondary metabolites, Flavonoid, Alkaloid, Terpenoid, Saponin**,** Urea Stress, Sodium Chloride Stress

1. INTRODUCTION

In the present world several researches and experiments are going on that are mainly focusing on how the life of people can be improved and make them free of diseases and other health related problems. In order to make life healthier people prefer traditional medicines made from medicinal plants other than pharmaceutically synthesized chemicals. Therefore, medicinal plants have always played a pivotal role as sources of drug lead compounds. Early humans, driven by their instinct, taste and experience, treated their illness by using plants; hence the history of medicinal plants is as long as the history of humans [1]. Demand for the medicinal plant is increasing with expansion in human needs, numbers and trade purposes. So many plants, especially wild species are more prone to harvesting and further synthesis of medicines. Therefore, cultivation of medicinal plants can decrease the amount to which wild populations are harvested. It will also help to preserve plant species from extinction and will promote socio economic growth [2]. Cultivating plants on a large scale would provide enough raw materials for the pharmaceutical industries. Systemic cultivation ensures the quality and purity of medicinal plants. Thereby collection of raw materials of crude drugs from cultivated plants gives a better yield in therapeutic quality.

Secondary metabolites are a diverse group of chemicals like phenolic compounds, alkaloids, flavonoids, saponins, etc. synthesized by plants mainly as defence compounds. The medicinal plants are rich in secondary metabolites. Alkaloids are secondary metabolites biosynthetically derived from amino acids resulting in a variety of chemical structures [3]. They have basic properties in which they are water soluble under neutral acid conditions and lipid soluble under neutral and basic conditions. This is especially important for dissolution in protonated form and membrane permeation in deprotonated form [4]. Abiotic stress caused by

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deficiencies or excesses in environmental factors including water, salt, light, temperature, and nutrients can substantially reduce plant growth and productivity and even survival [5]. Any abiotic stress or any change in the normal biological factor in the environment alters the different physiological, biochemical and metabolic function of plants and affect the plant growth where, plants protect themselves by acquiring various defence mechanism to prevent their negative effect on growth and production [6].

Salinization of soil or water adversely affects the photosynthesis, respiration, morphological and biochemical characteristics of the plants [7]. Salt stress often creates both ionic as well as osmotic stress resulting in accumulation or decrease of specific secondary metabolites in plants [8]. Alkaloids are found in about 20% of plant species in small quantities [9] and their production, extraction and processing remain major areas of research and development [10]. Saponins are another class of complex and chemically diverse group of compounds. The demand for saponins is increasing in medicinal research and applications. They are considered as the starting precursor for the semi-synthesis of steroidal drugs in the pharmaceutical industry [11]. Secondary metabolites play a major role in the adaptation of plants to the environment and in overcoming stress conditions [12]. In the growth conditions of plants, numerous secondary metabolites are produced by them to serve a variety of cellular functions essential for physiological processes. The type and concentration of secondary metabolites produced by a plant are determined by the species, genotype, physiology, developmental stage and environmental factors during growth. Recent researchers have found that stress and the subsequent defense response have led to the production of secondary metabolites in plants [13]. This implies that plants subjected to stresses can produce such compounds. Salt stress often creates both ionic as well as osmotic stress in plants. It leads to cellular degradation and reduction of cytosolic and vacuolar volumes resulting in accumulation or decrease of specific secondary metabolites in plants [8].

Application of nutrient elements can also affect the production of secondary metabolites. Incorporation of one or more trace elements could increase or decrease the production of secondary metabolites depending on the plant species as well as concentrations of these elements [14]. Plants produce increased secondary metabolites when exposed to stressful growth condition. For example, the salinity stress has induced the production of saponins, flavonoids, phenolics and photosynthetic pigments [15], the nitrogen fertilizer in excess amount has induced production of alkaloids [16]. Hence this stress application is being one of the main inductive techniques to enhance the secondary metabolites in many medicinal plants. This technique will aid to increase the natural compound concentration and compromise the demands in pharmaceutical industries and assist in farmers' welfare.

As a medicinally important plant which yield several secondary metabolites that are commercially important *Bacopa monnieri* (L.) Wettst was choosen to estimate the quantity of alkaloids and saponins on chemical stress application. Water hyssop and "Brahmi" are the two words used for *Bacopa monnieri* in the tradional system of medicine. According to National Medicinal Plants Board, New Delhi *Bacopa monnieri* (L.) Wettst. is identified for cultivation and conservation and denoted among the list of medicinal plants in high volume trade i.e., 2000-5000 metric ton annually. The whole plant including flowers can be used for medicinal purposes. It is used as a nerve tonic and cure for epilepsy, insanity, anaemia, dermatosis, arthritis, rheumatism, asthma, cough, diabetes, snakebite and ulcers. The plant contains alkaloids like brahmine, herpestine, nicotine and saponins like bacoside A and B, hersaponin, triterpenoid saponin and other compounds like stigmasterol, monnierin and α-mannitol. The plant is used as the principal ingredient of classical Ayurvedic preparations like Brahmighritam, Brahmirasayanam, Brahmi taila, Brahmi sarbat, etc. 'Memory Plus' is a product marketed in India that contains the standardised extracts of bacosides obtained from this plant which was made under the guidelines of herbal medicines issued by WHO. Because of its inherent potential in enhancing memory and vitality this plant has gained attention for its commercial cultivation globally. Stress is considered as a negative factor being responsible for severe yield losses in agriculture. However, with respect to spice and medicinal plants stress induces the production of secondary metabolites desirably. Based on these novel insights, stimuli for practical approaches for enhancing the production of secondary metabolites focused by deliberately applying moderate stress during their cultivation, *Bacopa monnieri.*

2. MATERIALS AND METHODS

2.1. Plant Description

The plant *Bacopa monnieri* is a small succulent herb with annual creeping nature. *Bacopa monnieri* also referred to as water hyssop and "Brahmi," has been used in the Indian system of medicine since time immemorial. It belongs to the family Scrophulariaceae and is found in wet, damp, and marshy areas. *Bacopa monnieri* is conventionally used for diverse ailments, but is best known as memory enhancer. A vast range of studies using methanolic and ethanolic extracts of this plant have shown its effect in treatment of wide range of diseases like diabetes, depression, cancer, inflammation etc. [17].

2.2. Collection of Plant Species

The plant *Bacopa monnieri* (L.) Wettst. was collected from Thiruvambady, Kozhikode (Dist), Kerala and grown under optimum growth conditions. The plant prefers wet and semi shade conditions with a temperature range between 15-40°C, humidity 65-80% and clayey loamy soil with acidic nature.

2.3. Cultivation Practices

Soil and climate, land preparation, Irrigation, weed control, fertilizer requirement, harvesting method are followed in standardized methods prescribed by National Medicinal Plants Board, New Delhi and Central Institute of Medicinal and Aromatic Plants, Resource Centre, Bangalore. Before removing the cuttings from the nursery, it should be flooded. The plants are dug out taking care to minimize the damage to the roots of the cuttings. Plant cuttings about 6-8cm long, containing nodes with roots are used for transplanting. One day before planting, vermicomposting is spread on the surface of the plots and mixed thoroughly with top 10 cm soil and then the land is flooded. The cuttings are transplanted in wet soil at spacing of 15 ×15 cm. Flood irrigation should be provided immediately after planting. For its proper growth daily irrigation, organic manuring and hand weeding should be done. By preferring all these conditions 10-15 stems of equal length were grown in fifteen different pots numbered 1 to 15 each filled with 5kg of soil on 09/12/2021.

2.4. Stress Application

The cultivated plantlets started to grow after three weeks (30/01/2022). Then the plants were subjected to chemical stress using urea and NaCl. The pots numbered 1, 2, 3 were kept as control. The normal level of urea preferred by the plant is 50mg urea/kg of soil. So the pots numbered 4, 5, 6 were treated with 100mg urea/kg of soil and the pots numbered 7, 8, 9 were treated with 200mg urea/kg of soil. The normal level of salt concentration that the plant prefers is below 100mM NaCl/L. So the pots numbered 10, 11, 12 were treated with 300mM NaCl and the pots numbered 13, 14, 15 were treated with 400mM NaCl. The growth of the plant was observed for another five days. Presence of yellow coloured leaves was observed in some stems of plants treated with urea and NaCl.

2.5. Preparation of Sample

After five days of observation, (on 4/2/2022) the plants kept as control and those subjected to chemical treatment were collected separately. Later kept for shade dry by storing separately. The dried samples were then powdered using a motor and pestle. Each sample was then weighed and stored separately. A part of sample has taken for soxhlet extraction using ethanol solvent, the extract has stored for certain quantification studies.

2.6. Quantitative Estimation of Phenolics

The sample extracts (50 µl of different solvent extracts) were added with Folin Ciocalteu reagent (0.5 ml, 1:1 diluted with distilled water) for 5 min and aqueous Na_2CO_3 (2.5 ml, 20%) was added. The mixture was vortexed, allowed to stand for 40 min at room temperature in dark and the phenols were determined by colorimetric method at 725 nm. The standard curve was prepared by 0, 5, 10, 15, 20 and 25 mg/ ml solutions of Gallic acid in methanol: water (50:50, v/v). Total phenol values are expressed in terms of Gallic acid equivalent. [18] (Siddhuraju and Becker, 2003).

2.7. Quantitative Estimation of Flavonoids

500 µl of all the plant extracts were taken in different test tubes. To each extract, 2 mL of distilled water was added. Then 150 mL of 5% $NaNO_2$ was added to all the test tubes followed by incubation at room temperature for 6 min. After incubation, 150 mL of $AlCl_3$ (10%) was added to all the test tubes including the blank. All the test tubes were incubated for 6 min at room temperature. Then 2 mL of 4% NaOH was added, which was made up to 5 mL using distilled water. The contents in all the test tubes were vortexes well, and were allowed to stand for 15 min at room temperature. The pink color developed because of the presence of flavonoids was read spectrophotometrically at 510 nm. Rutin was used for the calibration curve [19] (Zhishen et al.,

1998) and the results expressed as Rutin equivalents.

2.8. Quantitative Estimation of Terpenoids

Dried plant extract 100mg (wi) was taken and soaked in 9mL of ethanol for 24 hour [20]. The extract after filtration, was extracted with 10mL of petroleum ether using separating funnel. The ether extract was separated in pre-weighed glass vials and waited for its complete drying (wf). Ether was evaporated and the yield (%) of total terpenoids contents was measured by the formula (wi-wf/wi×100)

2.9. Quantitative Estimation of Alkaloids [21]

The quantitative estimation of alkaloid was carried for both control and urea treated plants. 1g of sample powder was dissolved in 10% acetic acid in ethanol and kept for 4 hours for each sample. Then the extracts were concentrated in water bath to one quarter of its original volume. Concentrated ammonium hydroxide is then added to the concentrated extracts for precipitation. The precipitate was collected and washed with dilute ammonium hydroxide and filtered. It is then dried, weighed and the result is expressed in percentage.

Percentage of alkaloid = (weight of alkaloid / weight of sample) × 100

2.10. Quantitative Estimation of Saponins

The quantitative estimation of saponin was carried according to the methodology of Ezeonu and Ejikeme [22] for both control and salt treated plants. 1g of sample powder was mixed with 20% of aqueous ethanol. The extracts were heated in water bath at 55°C with constant stirring for 4 hours. Then it was filtered and washed with aqueous ethanol. The mixture is then concentrated upto 4ml using water bath. The concentrated extract was then transferred into a separating funnel and mixed with 10ml diethyl ether. It was shaken well and the aqueous layer was recovered. The recovered aqueous layer was mixed with 6ml n-butanol, shaken well and the extract was recovered from it. The recovered extract was then washed twice with 10ml of 5% aqueous NaCl. The resulting solution is then heat dried, weighed and the result is expressed in percentage.

Percentage of saponin = (weight of saponin / weight of sample) × 100

The percentage of alkaloids and saponins were estimated and the range of difference is determined by comparing with control.

2.11. DPPH Radical Scavenging Activity

The hydrogen donating capacity was assessed by using stable DPPH method [23]. Briefly, a solution of 0.1mM DPPH was prepared using methanol. The samples (50- 250µg/mL) were mixed with 5.0mL of DPPH solution. Reaction mixture was shaken, incubated at 27°C for 20 min and the absorbance was measured at 517 nm. Results were compared with the activity of rutin. Percent DPPH discolouration of the sample was calculated using the formula:

DPPH radical scavenging activity (%) = [(Control OD - Sample OD) / Control OD] × 100.

3. RESULTS AND DISCUSSION

3.1. Growth of *Bacopa monnieri* under Ideal Condition

The plant grows well in wet and semi shade conditions. Stems are used to propagate. After three weeks from planting roots arose at nodes and the plant started to grow and new leaves arise at nodes. Stems showed creeping nature. The leaves formed were about 0.4 – 2.8cm long and 0.15 – 0.8 cm wide (Fig. 1).

Figure 1. *Baccopa monnieri* cultivated in different pots

3.2. Morphological Changes under Stress

The salt stress induces ionic and osmotic stress in plants leading to alterations in biochemical processes that result in morphological changes. The nitrogen containing urea when provided in excess amounts leads to several internal changes which is exhibited through morphology. Both the urea and salt treated plants showed presence of yellow coloured leaves in some stems as a result of the stress and as a mechanism to withstand it. Complete colour changes or wilting or death of the plants has

not been observed in this treatment throughout the study. Hence this study proves the concentration which is used in this study is not causes the serious effect in plant life.

3.3. Extraction Yield

The yield of plant extract in ethanol is shown in the Table 1. In urea applied plants the extract yield is higher for medium dose treated plant, which is 5.77% and the control plant having low yield of 5.08%. In NaCl applied plants high yield of extract got in control plant which is 5.71% and medium dose applied plant having low yield of 5.22% (Table 1).

Table 1. Extraction yield of *Bacopa monnieri*

Concentration of urea applied (mg)	Extract yield (%)	Concentration of NaCl applied (mM)	Extract yield (%)
Lower dose (250 mg)	5.08	Lower dose (100 mM)	**5.71**
Medium dose (500 mg)	**5.77**	Medium dose (300 mM)	5.22
Higher dose (1000 mg)	5.17	Higher dose (400 mM)	5.70

Lower dose- normal requirement of the plant; Medium dose and higher dose- stress applied doses

3.4. Quantitative Estimation of Total Phenolic Contents

The contents of total phenols present in both plants kept as control and those treated with NaCl that were measured by Folin Ciocalteu reagent in terms of gallic acid equivalent. The total phenol varied from 1812.25 to 2057.125 µg GE/mg. The result showed that more amount of phenolics were synthesized in those plants treated with 400mM NaCl/Kg of soil when compared to that of plants kept as lower dose stress treatment (Table 2).

Stress caused by NaCl induced an accumulation of proline, total phenolics and other antioxidants in rosemary (*Rosmarinus officinalis*) [24]. The total phenolic content of sprouts of radish treated with 100 mM of NaCl was significantly increased, which is similar to that of *Cakile maritima* and red pepper reported by Ksouri et al. [25]. The quantity of total phenols was observed to be 24.75 mg GAE/gm methanolic extract of *Bacopa* [26].

Table 2. Quantitative estimation of total phenolic and saponin contents

Concentration of NaCl applied (mM)	Phenolics µg GE/mg	Saponin (%)
Lower dose (100 mM)	1812.25±0.10	12.23%
Medium dose (300 mM)	1915.54±0.035	17.2%
Higher dose (400 mM)	**2057.125±0.05**	**25.56%**

Values are mean ± Standard Deviation
Lower dose- normal requirement of the plant; Medium dose and higher dose- stress applied doses

3.5. Quantitative Estimation of Saponins

The saponin content present in both plants kept as control and those treated with NaCl is shown in Table 2. It represents the saponin of the control is 12.23%, it was exceeded for the salt treatment plants 300mM and 400mM as 17.25 and 25.56% respectively. The result showed that more amount of saponins were synthesized in those plants treated with 400mM NaCl when compared to that of plants kept as control and lower dose stress treatment.

In the phytochemical analysis of *Bacopa monnieri* the quantitative estimation of saponins (mg/g dry weight) has showed that root contains 7.50±0.71, stem contains 23.33±1.53 and leaf contains 57.00±2.65 saponins [27]. In another phytochemical study the quantitative analysis of saponins in the whole plant was 1.5 mg/g dry matter of plant extract [26]. The phytochemical studies upon the plant after growing under salinity and drought stress in *in-vitro* condition has induced increase in proline content more than 20 times than that of the control [28]. In another study of growing the plant in salt stressed conditions by applying halotolerant rhizobacteria showed higher levels of proline and biomass yield [29]. So the increase in synthesis of secondary metabolites can be achieved through stress application which opens a wider scope in the near future.

3.6. Quantitative Estimation of Flavonoids, Terpenoid Content

The flavonoid content present in both plant kept as control and those treated with urea is shown in Table 3. The flavonoid varied from 95.68 to 450.72 µg RE/mg. The result showed that more amount of flavanoids were synthesized in those plants treated with 500mg urea/Kg soil when compared to that of plants kept as lower and higher dose stress treatment. The higher dose of urea (1000mg/kg soil) synthesized only 161.25 µg RE/mg; it seems the stress applied with higher concentration of urea affects the flavonoid production. Increases in flavonoids under low N supply might also be attributed to promoting deamination of phenylalanine to cinnamic acid due to nitrogen deficiency [30]. The flavonoids in tomato, Arabidopsis and alfalfa root decreased with increasing N supply [31]. Total flavonoid content of *Bacopa monnieri* (L.) at 10 µg was recorded as 6.333 GAE and at 1000 µg it increased to 29.666GAE [26].

The terpenoid content present in both plant kept as control and those treated with urea is shown in Table 3. It is revealed from the result that the control plant gives 15% terpenoids which is lesser than the 100 mg/kg urea treated which is 28% and 200 mg/kg urea treated which is 36%. The result showed that the more amount of terpenoids were synthesized in those plants treated with 200 mg/kg of soil when compared to that of plants kept as control and lower dose stress treatment. Under moderate nutrient soil concentrations, N and P do not limit terpenoid production, because plants may take up enough N and P to fulfil their requirements for growth and terpenoid synthesis [32]. The concentrations of most of the terpenoids identified in the plant material were significantly influenced by N supply, yet the response varied between different groups of terpenoids [33]. *Bacopa monnieri* (L) was reported to possess terpenoids and steroids predominately in ethanol, aqueous, chloroform, acetone and ethyl acetate extracts [34].

3.7. Quantitative Estimation of Alkaloids

The alkaloid content present in both plants kept as control and those treated with urea is shown in Table 3. The data being responsible for that the control plants gives 22.2% alkaloids which is lesser than the 100mg/kg urea treated which is 49.4% and 200 mg/kg urea treated which is 71.4%. The results showed that more amount of alkaloids were synthesized in those plants treated with 200 mg urea/kg of soil when compared to that of plants kept as control and lower dose stress treatment.

In a scientific study, the phytochemical analysis of *Bacopa monnieri* provides the quantitative estimation of alkaloids (mg/g dried weight) has showed that root contains 1.67±0.577, stem contains 47.00±0.81 and leaf contains 53.07±2.08 alkaloids [27]. In another phytochemical study the quantitative analysis of alkaloids in the whole plant was 110mg/g dry matter of plant extract [26]. It was revealed that the quantity of alkaloids was enhanced in *Catharanthus roseus* through the effect of nitrogen fertilization when compared with its parental variety [16]. Thus the study revealed that a good amount of alkaloid can be enhanced through stress application by various biotic and abiotic factors which has a lot of scope in the pharmaceutical industry.

Table 3. Quantitative estimation of flavonoids, terpenoid and alkaloid content

Concentration of urea applied (mg)	Flavonoids µg RE/mg	Terpenoids (%)	Alkaloids (%)
Lower dose (250 mg) Control	95.68±0.14	15	22.2%
Medium dose (500 mg)	**450.72±0.56**	28	49.4%
Higher dose (1000 mg)	161.25±0.47	**36**	71.4%

Values are mean ± Standard Deviation
Lower dose- normal requirement of the plant; Medium dose and higher dose- stress applied doses

3.8. DPPH Radical Scavenging Activity

Antioxidants through their scavenging power are useful for the management of these diseases. DPPH stable free radical scavenging method is an easy, rapid and sensitive way to survey the antioxidant activity of a specific compound or plant extracts [23].

The antioxidant activity is increased in urea treated plants and there is decrease of antioxidant activity in NaCl treated plants. In urea treated plants, the control plants show minimum antioxidant activity of 11.91±0.547, while 1g/kg urea treated plants show high activity (19.97±0.039 %) as compared to other two dose (Table 4). In NaCl applied plants, the control plants show high antioxidant activity of 22.32±1.6 as compared to two other doses. Though the phenolic compounds are much increased in higher dose of NaCl stress application, the antioxidant activity has reduced. It shows other metabolites interfere the radical scavenging activity of the plant extract. It should be focused and traced to find the active and inhibitory metabolites of *B. monnieri* through further research works.

Table 4. Determination of antioxidant activity through DPPH radical scavenging activity

Concentration of NaCl Stress applied (mM)	DPPH radical inhibition (%)@ 60µg of extract	Concentration of Urea stress applied (mg)	DPPH radical inhibition (%) @ 60µg of extract
Lower dose (100 mM)	**22.32±1.6**	**Lower dose (250 mg)**	11.91±0.54
Medium dose (300 mM)	16.10±1.49	**Medium dose (500 mg)**	15.40±0.49
Higher dose (400 mM)	8.64±0.99	**Higher dose (1000 mg)**	**19.97±0.039**

Values are mean ± Standard Deviation
Lower dose- normal requirement of the plant; Medium dose and higher dose- stress applied doses

In another research study of *Mitracarpus scaber* the phytochemical screening of crude methanolic extract revealed the presence of saponins, tannins, flavonoids, essential oil and glycosides. The antioxidant activity using DPPH analysis shows that the high antioxidant capacity [35]. Methanolic extracts of *Chromolaena odorata* showed higher free radical scavenging capacity and phytochemical analysis revealed the presence of tannins, phlorotannins, steroids, terpenoids, flavonoids and saponins [36]. Non-enzymatic antioxidants like cysteine, non-protein thiol, proline, carotenoids and ascorbic acid may play a role in inducing resistance to salinity by protecting labile macromolecules against attack by free radicals which are formed during various metabolic reactions leading to oxidative stress [37, 38].Among the eight different concentrations (20 to 800µg/ml) of ascorbic acid and leaf extracts of two plant sources, the highest scavenging activities were 96.86%, 75.85% and 86.02%, respectively for ascorbic acid, *B. monniera* and *C. grandis* at 800µg/ml concentration with similar extract of the aerial parts of *B. monnieri* also noted concentration dependent scavenging activities [39].

Plant medicinal properties are well known and many are yet to be discovered. Almost all the parts of the plant namely stem, leaves, flowers, fruits, roots and seeds are known to have medicinal properties based on the chemical components present in it. These parts can be used to extract medicinally important compounds. They can be utilized to cure several diseases and lead a better life. The medicinal properties of plants have greatly contributed to the pharmaceutical industry. There are several herbal therapies available to treat several ailments.

4. CONCLUSION

The higher amount of saponins, phenolics produced in plants treated with NaCl. A higher dose of urea increased the production of flavonoids and terpenoids than alkaloids. The antioxidant activity is increased in urea treated plants and there is decrease of antioxidant activity in NaCl treated plants. The study proves that there is production of secondary metabolites during stress conditions in the plant *Bacopa monnieri*. Production is higher in such treated plants when compared to plants kept as controls. This piece of research has paved a way for its improved commercial production of attested compounds/drug. Further, the researchers can also proceed with other research analysis based on compounds synthesized through the application of different stresses to this plant.

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RESEARCH ARTICLE

An inventory of invasive alien species in Anuvavi Hills, Coimbatore District, Tamil Nadu, India

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ABSTRACT

Invasive alien species pose a significant threat to global biodiversity and ecological balance. This study aimed to document and assess invasive alien species' diversity, distribution, and potential impacts in Anuvavi Hills, Coimbatore district, India. Extensive field surveys were conducted within Anuvavi Hills from August 2023 to February 2024 to record invasive alien species. The collected specimens were identified, classified, and grouped based on their life forms and families. A total of 68 invasive alien species belonging to 29 families and 57 genera were documented. Dicotyledons were dominant, with 64 species, while monocotyledons comprised 4 species. The Asteraceae family had the highest species richness, followed by Amaranthaceae, Tiliaceae, Caesalpiniaceae, Cleomaceae, Euphorbiaceae, Malvaceae, and Mimosaceae. Herbs constituted the majority of life forms, followed by shrubs, climbers, and trees. This study contributes to the growing body of knowledge on invasive alien species in India. The findings suggest that Anuvavi Hills harbors a diverse array of invasive alien species, highlighting the need for effective management strategies to mitigate their potential impacts on native ecosystems. The documented species have various uses in traditional medicine, ornamental gardening, and fodder, but some may also pose threats to human health and biodiversity.

Keywords: Anuvavi hills, biodiversity, ecological impacts, invasive alien species

1. INTRODUCTION

Invasive species have spread extensively across all categories of living organisms and ecosystems worldwide [1]. These species may be introduced either inadvertently or deliberately [2] and they exhibit distinctive traits, including fast reproduction and growth, strong dispersal abilities, remarkable adaptability to various ecological settings, resilience to diverse soil and climate conditions, abundant seed production facilitating easy dispersal, rapid dissemination rates, prolonged flowering and fruiting periods, aggressive root system growth, short generational spans, and wide native distribution ranges [3]. The encroachment of alien plant species into new environments has emerged as the second most significant peril to plant diversity after habitat loss [4]. The International Union for Conservation of Nature and Natural Resources (IUCN) describes "alien invasive species" as non-indigenous organisms that take root in natural or semi-natural habitats, acting as agents of disruption and endangering native biodiversity. Exotics are termed biological pollutants for their detrimental impacts on both natural and human-controlled ecosystems. The profound ecological ramifications of swiftly spreading introduced vegetation and non-native plant species pose a significant menace to biodiversity [5]. Roughly 10% of the globe's vascular plants possess the capability to infiltrate different ecosystems and influence indigenous organisms either directly or indirectly. In India, approximately 18% of the flora consists of non-native species, with American species comprising 55%, Asian and Malaysian species 30%, and European and Central Asian species 15%. The necessity for a comprehensive regional and national database on invasive non-native species is evident, as it would facilitate monitoring their distribution and impact across different regions, enabling the development of effective management strategies [6]. Considering these impacts, the present study was conducted to document the invasive alien species in Anuvavi Hills, Coimbatore district.

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2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in Anuvavi Hills [Figure 1], situated at coordinates 11º03.5'N and 76º50.9'E, with an elevation of 690 meters above sea level, are found along the Anaikatty Highway, approximately 22 kilometers southwest of Coimbatore city. This region serves as a convergence point between a branch of the Western Ghats and the plains of Coimbatore. The plains themselves are a patchwork of cultivated lands interspersed with both small and large-scale brick factories. The predominant vegetation in the area is classified as dry deciduous and grassland.

2.2. Data Collection

The field survey was carried out from August 2023 to February 2024 in Anuvavi Hills, Coimbatore district. During the field visit, a total of 5 field trips were conducted, documenting various invasive alien species and observing their morphological characteristics in their natural state. Comprehensive data were recorded in the field notes. The collection of invasive alien species spanned across diverse localities within the study area, including rural regions, agricultural lands, wastelands, roadsides, ponds, moist areas, and stream banks. Additionally, photographs were captured during the field visits, depicting the study regions and different alien plant species. Subsequently, the plants were identified utilizing resources such as the Flora of the Presidency of Madras [7], Flora of Tamil Nadu Carnatic [8], and Flora of Tamil Nadu [9].

Figure 1. Overview of the Study Area

3. RESULTS AND DISCUSSION

In this present survey, a total of 68 invasive alien species belonging to 29 families and 57 genera were documented in Anuvavi Hills, Coimbatore district. Among them, dicotyledons were 64 species with polypetalae 23, gamopetalae 26 and monochlamydeae 15 species, and monocotyledons with 4 species respectively [Table 1 and Figure 2]. The Asteraceae family was the dominant contribution to 12 species followed by Amaranthaceae with 9 species, Tiliaceae with 4 species, Caesalpiniaceae, Cleomaceae, Euphorbiaceae, Malvaceae, and Mimosaceae families with 3 species, and the remaining families were one or two species in each were depicted in Figure 2. The extensive inventory of invasive alien flora in India [10] and China [11] reported Asteraceae as the predominant family. The documented species are grouped into different lifeforms and herbs were dominantly present in 78% (53 species) followed by shrubs at 12% (8 species), Climbers at 6% (4 species), and Trees at 3% (3 species) were represented in Figure 3. [12] also reported that the lifeform analysis of the documented invasive alien flora showed that herbaceous species constitute the major life form with 73.47% respectively. Among 57 genera the *Alternanthera* and *Corchorus* have a maximum contribution of 4 species dominantly in the study area followed by *Cassia* and *Cleome* with 3 species and *Ipomoea* and *Euphorbia* with 2 species in each, while the remaining genera are monogeneric with a single genus.

Most of the species are commonly used in several aspects such as green vegetables, medicine, ornamental, fodder, and fuel wood by local peoples. Among 9 species are green vegetables namely

Alternanthera tenella, A. sessilis, Amaranthus spinosus, Boerhavia erecta, Cassia obtusifolia, Celosia argentea, Digera muricata, Eclipta prostrata and *Portulaca oleraceae* most of the species are collected in their surroundings some species are commonly cultivated and weekly once or twice consumed by rural peoples. Nowadays the local people commonly use *Alternanthera philoxeroides,* a highly toxic weed generally grown in polluted sewage areas and the plant accumulates heavy metals in its roots and leaves. According to [13], when it is consumed as a vegetable by humans and cattle as feed, it can cause serious health hazards and even sometimes lead to death. Hence, the awareness of correctly identified *Alternanthera sessilis* is very essential for society and it controls the health risks of livestock and humans. It treats stomach disorders, diarrhea, dysentery, wounds, fever, vomiting blood, headaches, and vertigo [14].

However, some alien species are highly used in our traditional medicinal systems in Siddha and Ayurveda. In this investigation, we observed 9 alien species namely *Achyranthes aspera, Calotropis gigantea, Cleome gynandra, Eclipta prostrata, Mimosa pudica, Spermacoce hispida, Tridax procumbens, Tribulus terrestris* and *Vernonia cinerea* are medicinally important and commonly used by local peoples for healthcare. Otherwise, some species such as *Lantana camera, Mirabilis jalapa,* and *Antigonon leptopus* are grown in home gardens for ornamental purposes; while the *Leucaena leucocephala* is commonly grown in hedges for fodder. These are some beneficial effects of alien species in this region. Previously some authors have documented the invasive alien species threats and uses in various regions of Tamil Nadu. [15] studied 93 weed species belonging to 85 genera and 42 families in the Kanyakumari district and their medicinal value in rural healthcare.

Most of the alien species are highly hazardous to the native flora and fauna diversity worldwide. These plant seeds with good germination quality and survival in all climates are the main reason for easily spreading out worldwide and these weeds are directly or indirectly changing their native biodiversity. In the present field observation, the *Parthenium hysterophorus, Lantana camera, Prosopis juliflora, Eichhornia crassipes, Xanthium indicum, Argemone mexicana, Ageratum conyzoides,* and *Hyptis suaveolens* are highly affected the natural biodiversity and agricultural fields in the study area. Hence, the *Parthenium hysterophorus* is allergens that affect humans and livestock. The plant produces allelopathic chemicals that suppress crop and pasture plants [16]. These species are easily spread out in vigorous growths and occupy the largest area in a short period which has severe effects on native plant diversity [17]. It is well known that invasive species compete with indigenous species for nutrition, light, water, and space. Hence continuous monitoring and control of the spread of those species is important to protect native species from extinction.

***Bidens pilosa* L.**

***Aerva javanica* (Burm.f.)**

***Prosopis juliflora* (Sw.) DC.**

Figure 2. Images of some invasive alien species documented in the study area

Table 1. List of invasive alien species in the study area

S.No.	Binomial Name	Family Name	Habit	Origin	Location	Uses
1.	*Acanthospermum hispidum* L.	Asteraceae	Herb	Tropical America	Wasteland	Medicinal
2.	*Achyranthes aspera* Ros.	Amaranthaceae	Herb	South-East Asia	Roadsides	Medicinal
3.	*Aerva javanica* (Burm.f.)	Amaranthaceae	Herb	Tropical Africa	Wasteland	Medicinal
4.	*Ageratum conyzoides* L.	Asteraceae	Herb	Tropical America	Agriculture field	Medicinal
5.	*Alternanthera pungens* Kunth.	Amaranthaceae	Herb	Tropical America	Wasteland	Fodder
6.	*Alternanthera sessilis* (L.) Kr. Br	Amaranthaceae	Herb	Tropical America	Agriculture field	Fodder
7.	*Alternanthera philoxeroides* (Mart) Griseb.	Amaranthaceae	Herb	Southern America	Aquatic region	None
8.	*Alternanthera tenella* Colla.	Amaranthaceae	Herb	Tropical America	Aquatic region	Medicinal
9.	*Amaranthus spinosus* L.	Amaranthaceae	Herb	Tropical America	Wasteland	Vegetable
10.	*Antigonon leptopus* Hook & Arn.	Polygonaceae	Climber	Northern America	Roadsides	Ornamental

11.	*Aregemone mexicana* L.	Papaveraceae	Herb	Southern America	Wasteland	Medicinal
12.	*Ascelpias curassavica* L.	Asclepiadaceae	Herb	Tropical America	Aquatic region	Medicinal
13.	*Bidens pilosa* L.	Asteraceae	Herb	Southern America	Wasteland	Fodder
14.	*Blainvillea acmella* L.	Asteraceae	Herb	Tropical Asia	Roadsides	Medicinal
15.	*Boerhavia erecta* L.	Nyctaginaceae	Herb	Tropical America	Roadsides	Medicinal
16.	*Borassus flabellifer* L.	Arecaceae	Tree	Southern Asia	Roadsides	Medicinal
17.	*Cathranthus pusilus* (Murr.) G. Don	Apocyanaceae	Herb	Tropical Asia	Agriculture field	Ornamental
18.	*Calotropis gigantea* (L.) W. T. Aiton	Asclepiadaceae	Shrub	Tropical Asia	Wasteland	Medicinal
19.	*Cassia absus* L.	Caesalpiniaceae	Herb	Tropical Asia	Roadsides	Medicinal
20.	*Cassia obtusifolia* L.	Caesalpiniaceae	Herb	Central & South America	Roadsides	Medicinal
21.	*Cassia hirusta* L.	Caesalpiniaceae	Shrub	Tropical America	Wasteland	Medicinal
22.	*Celosia argentea* L.	Amaranthaceae	Herb	Tropical Africa	Agriculture field	Medicinal
23.	*Chloris barbata* (L.) Swartz	Poaceae	Herb	Tropical America	Wasteland	Fodder
24.	*Chormolaena odarata* (L.) R. King	Asteraceae	Herb	Tropical America	Wasteland	Medicinal
25.	*Cleome monophylla* L.	Cleomaceae	Herb	Tropical Africa	Agriculture field	Fodder
26.	*Cleome gynandra* L.	Cleomaceae	Herb	Tropical Africa	Wasteland	Medicinal
27.	*Cleome viscosa* L.	Cleomaceae	Herb	Tropical America	Wasteland	Medicinal
28.	*Corchorus aestuans* L.	Tiliaceae	Herb	Tropical Africa	Agriculture field	Medicinal
29.	*Corchorus fascicularis* Lam.	Tiliaceae	Herb	Tropical Africa	Agriculture field	Medicinal
30.	*Corchorus tridens* L.	Tiliaceae	Herb	Tropical Africa & Asia	Roadsides	Fibre
31.	*Corchorus trilocularis* L.	Tiliaceae	Herb	Tropical Africa	Roadsides	Fibre

32.	*Crotalaria pallida* Aiton	Fabaceae	Herb	Tropical Africa & Asia	Roadsides	Fodder
33.	*Croton bonplandianum* Baill.	Euphorbiaceae	Herb	Southern America	Wasteland	Fodder
34.	*Cuscutta reflexa* Roxb.	Cuscutaceae	Climber	Indian subcontinent	Roadsides	Medicinal
35.	*Cyperus iria* L.	Cyperaceae	Herb	Tropical America	Aquatic region	Fodder, Fibre
36.	*Digera muricata* (Roxb.) R. Br.	Amaranthaceae	Herb	Tropical Asia & Africa	Agriculture field	Medicinal
37.	*Datura innoxia* P. Miller.	Solanaceae	Shrub	Tropical America	Wasteland	Medicinal
38.	*Eclipta prostrata* L.	Asteraceae	Herb	Northern America	Aquatic region	Medicinal
39.	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Herb	Southern America	Aquatic region	Medicinal
40.	*Emilia sonchifolia* (L.) DC.	Asteraceae	Herb	Tropical Asia	Agriculture field	Medicinal
41.	*Euphorbia heterophylla* L.	Euphorbiaceae	Herb	Tropical America	Roadsides	Ornamental
42.	*Euphorbia hypercifolia* L.	Euphorbiaceae	Shrub	Tropical America	Aquatic region	Ornamental
43.	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Shrub	Tropical America	Wasteland	Medicinal
44.	*Indigofera linnaei* Ali.	Fabaceae	Herb	Northern Australia	Wasteland	Fodder
45.	*Ipomoea carnea* Jacq.	Convolvulaceae	Shrub	Southern America	Aquatic region	Medicinal
46.	*Ipomoea obscura* (L.) Ker Gawler	Convolvulaceae	Climber	Tropical Africa	Aquatic region	Medicinal
47.	*Leucaena leucocephala* (Lam.) Dewit.	Mimosaceae	Tree	Southern Mexico	Roadsides	Fodder
48.	*Lantana camara* L.	Verbinaceae	Shrub	Tropical America	Roadsides	Medicinal, Ornamental
49.	*Mimosa pudica* L.	Mimosaceae	Herb	Tropical America	Aquatic region	Medicinal

50.	*Mirabilis jalapa* L.	Nyctaginaceae	Shrub	Tropical America	Roadsides	Medicinal
51.	*Malvastrum coromandelianum* L.	Malvaceae	Herb	Northern & Southern America	Roadsides	Medicinal
52.	*Ocimum americanaum* L.	Lamiaceae	Herb	Tropical America	Wasteland	Medicinal
53.	*Parthenium hysterosporus* L.	Asteraceae	Herb	Tropical America	Wasteland	Fodder
54.	*Peristrope paniculata* (Forssk.) R. K. Brummitt	Acanthaceae	Herb	Tropical Africa	Wasteland	Medicinal, Fodder
55.	*Prosopis juliflora* (Sw.) DC.	Mimosaceae	Tree	Mexico & South America	Wasteland	Fuelwood
56.	*Portulaca oleracea* L.	Portulacaceae	Herb	Europe	Agriculture field	Vegetable, Medicinal
57.	*Passiflora foetida* L.	Passifloraceae	Climber	Tropical America	Wasteland	Medicinal
58.	*Ruellia tuberosa* L.	Acanthaceae	Herb	Central America	Aquatic region	Ornamental
59.	*Sida acuta* Burm. f.	Malvaceae	Herb	Central America	Roadsides	Medicinal
60.	*Spermacoce hispida* L.	Rubiaceae	Herb	Tropical Asia	Wasteland	Medicinal
61.	*Stachytarpheta jamaicensis* (L.) Gaertin.	Verbinaceae	Herb	Tropical America	Roadsides	Medicinal, Ornamental
62.	*Synedrella nodiflora* (L.) Vahl.	Asteraceae	Herb	Tropical America	Wasteland	Ornamental
63.	*Tridax procumbens* L.	Asteraceae	Herb	Tropical America	Roadsides	Medicinal
64.	*Tribulus terrestris* L.	Zygophyllaceae	Herb	Southern Eurasia & Africa	Roadsides	Medicinal
65.	*Urena lobata* L.	Malvaceae	Herb	Tropical Asia & America	Wasteland	Medicinal
66.	*Vernonia cinerea* (L.) Less.	Asteraceae	Herb	Tropical Asia	Roadsides	Medicinal
67.	*Waltheria indica* L.	Sterculiaceae	Herb	Tropical America	Wasteland	Medicinal
68.	*Xanthium indicum* L.	Asteraceae	Herb	Northern America	Wasteland	Medicinal

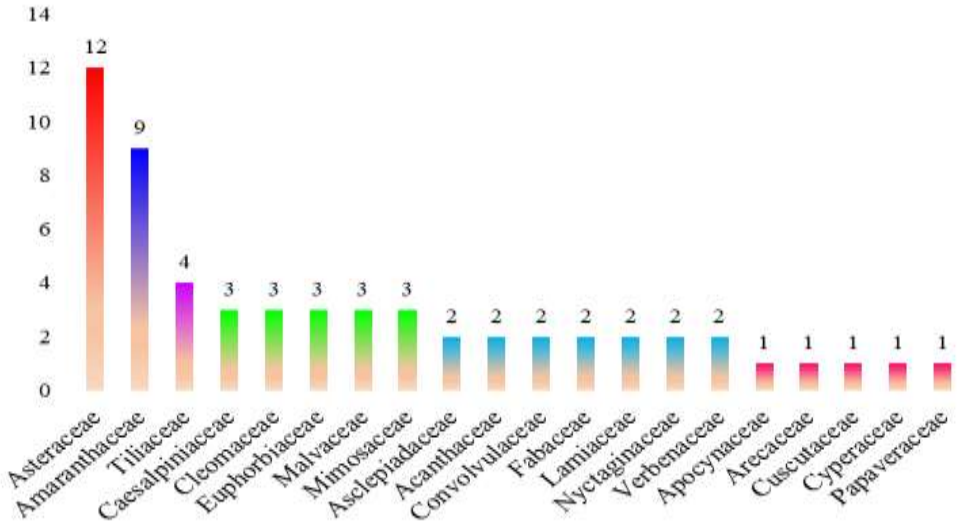

Figure 3. Family-wise analysis of Alien species in Anuvavi Hills, Coimbatore District

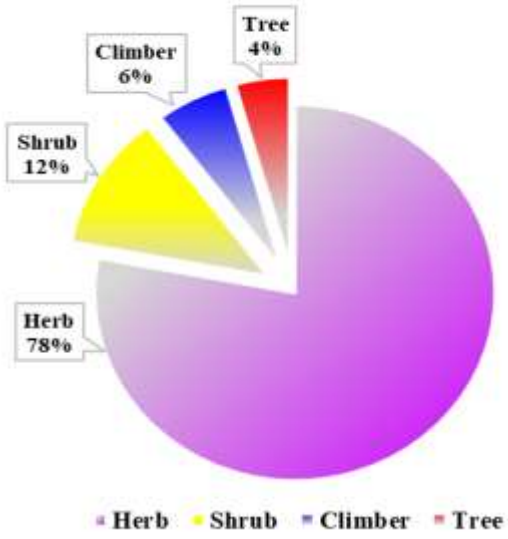

Figure 4. Lifeform-wise analysis of alien species in Anuvavi Hills, Coimbatore District

4. CONCLUSION

The present survey in Anuvavi Hills, Coimbatore district, identified 68 invasive alien species across 29 families and 57 genera, with Asteraceae being the most dominant family. Herbaceous species prevailed, reflecting their abundance in the area. While some species are utilized by locals for various purposes, others pose significant health and environmental risks, such as Alternanthera philoxeroides. Despite some beneficial uses, invasive species threaten native biodiversity and agriculture, as seen with *Parthenium hysterophorus*. Continuous monitoring and control efforts are essential to mitigate their impact and safeguard ecosystems.

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REVIEW ARTICLE

A review on the ethnopharmacological and therapeutic aspects of *TINOSPORA CORDIFOLIA* THUNB. of menispermaceae family

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ABSTRACT

Tinospora cordifolia Thunb. commonly known as Guduchi is one of the most important medicinal herbaceous vine belonging to the family Menispermaceae which have relatively fewer documented medicinal plants compared to other families. *Menispermaceae* family is native to India's tropical regions, Myanmar and Srilanka, consisting of about73 genera and about 320 species. Among them *Tinospora cordifolia* is well known for its medicinal value and therapeutic potentials. The whole plant is utilised in both traditional and modern medical system due to the presence of high alkaloid content in its stem and leaf parts. *T. cordifolia* is mostly distributed in India, China, Thailand, Myanmar, Philippines, Indonesia and Africa and typically thrive well in dry deciduous forests in an altitude up to 1000ft. This plant is renowned for its antioxidant, anti-inflammatory, anti-hyperglycaemic and immunomodulatory properties. Major phytochemical componds including alkaloids, steroids, glycosides, diterpenoid lactones, sesquiterpenoids etc are present. *T.cordifolia* is widely used for the preparation of various herbal medicines and it is mentioned as 'Rasayana' in Ayurvedic medicine due to its power to rejuvenate and improve the immune system. Its plant parts are commonly used to treat diseases such as bronchitis, syphilis, ulcers, jaundice, piles, urinary tract infections, skin problems and liver diseases. This review aims to highlight the traditional and ethnopharmacological significance of *Tinospora cordifolia* in the current scenario of increasing demand for plant-based products for the treatment of chronic diseases worldwide.

Keywords: *Tinospora cordifolia*, ethnopharmacology, pharmacology, phytochemistry, therapeutic

1. INTRODUCTION

Using medicinal plants for healing is a therapeutic practice that is as old as humanity. There is copious evidence from a variety of sources (written papers, preserved monuments, and even original plant medicines) supporting the ancient human hunt for pharmaceuticals in nature**.** Due to the growing adoption of herbal healthcare methods, medicinal plants have become more significant in recent times. This is because of the existence of bioactive chemicals which gives them a wide range of pharmacological effects [1].

Tinospora cordifolia Thunb., is an evergreen perennial climber. This plant is a member of the family *Menispermaceae* and is deciduous and dioecious. In the Indian medical system, the herb is known as 'Rasayana' and holds great therapeutic significance. Modern medicine has acknowledged its effectiveness as well. *T. cordifolia* grows on a variety of tree species and is native to lower elevations in tropical regions of the Indian subcontinent. It requires a moderate amount of soil moisture and prefers a wide range of soil types, from acidic to alkaline [2]. Growing on a variety of hedges and trees, *T. cordifolia* is a huge, widely spreading, glabrous, dioecious perennial deciduous climber. According to reports, it bears separate male and female blooms. When the stem is young, it has green succulent bark that is covered by a thin layer of brown bark. When the stem dries out and the bark separates from the wood, it is dotted with warty lenticels. Branches produce thin, pendulous, fleshy roots that are terete, striate, and have tubercled, pale, occasionally glossy, or glabrous bark [2].

India has long utilised medicinal herb, *Tinospora cordifolia* Thunb. in folkloric and Ayurvedic treatments. Due to the presence of several chemicals of pharmacological significance that fall into diverse classes, including steroids, sesquiterpenoid, glycosides, alkaloids, and phenolics, all parts of the plant are incredibly valuable. These substances are hepatoprotective,

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immunomodulatory, anti-inflammatory, antipyretic, antidiabetic, and antioxidant due to their pharmacological characteristics [3].

T. cordifolia is used to treat several illnesses, including fever, dyspepsia, jaundice, asthma, diabetes, skin conditions, and persistent diarrhoea and dysentery. It is also essential in the management of helmenthiasis, rheumatoid arthritis, leprosy, and cardiac problems [4]. In traditional medicine, the root and stem parts are used as a counter measure against scorpion stings and snake bites. The stem is diuretic, bitter, stomachic, and increases bile secretions in addition to quelling thirst, enhancing blood quality, and treating jaundice. The stem juice helps with urethral and vaginal discharges, indigestion, and diabetes; while root and stem powder are used to treat cancer. In Ayurveda it is denoted as 'Amrita' for its usage for regeneration. Significant pharmacopoeias also have references related to this medicinal plant [4].

2. REVIEW OF LITERATURE

2.1. Ethnopharmacological aspects of *T. cordifolia*

T. cordifolia gained a significant attention since it is used in several regions of the nation in traditional and tribal medicine. The Baiga tribe, lives in Uttar Pradesh, produce paste from the stem of Guduchi (*T. cordifolia*). The medication was made and administered to treat fever [5]. *T. cordifolia* is used as a medicament by the seacoast fisherman and tribal people of Bombay and its surrounding areas to cure fever, jaundice, chronic diarrhea, and dysentery [6]. The tribals of Bigwada, Rajasthan, and Jammu & Kashmir, use stem decoction orally to treat fever [7]. The herb is used on a daily basis by the tribal people of the Khedbrahma region of North Gujarat as food and medicine. For the treatment of cancer, the powdered root and stem bark of *T. cordifolia* were combined with milk [8]. The Gujjar and Backwal Muslim tribes of Rajouri, Jammu (Tawi) used the herb to treat bone fractures [9].

In the Dahanu forest section of Maharashtra, tribal races such as Agaris, Bhils, Dho-dias, Dublas, Khakaris, Rimoshis, Thakurs, Vardaris, Vagharis, and Varlis utilize its stem decoction with cold or hot water (approximately 3-4 grams) in the morning on an empty stomach as a tonic for general weakness [10]. The inhabitants in Patiyala (Punjab) use two drops of the leaf juice to cure ear discomfort [11]. Tribals of Madhya Pradesh Harda District utilize this plant to treat fever, dysentery, diarrhea, piles, skin ailments, rheumatism, bronchitis, asthma, gynecological disorders, abortion, and snake bite [12].

2.2. Phytochemical constituents of *T. cordifolia*

Aerial and root parts of *T. cordifolia* have been reported to contain various phytochemical constituents. In the early 1900s, the plant was found to contain giloin, gilenin, and gilosterol, as well as bitter components such columbin, chasmanthin, and palmarin [13].

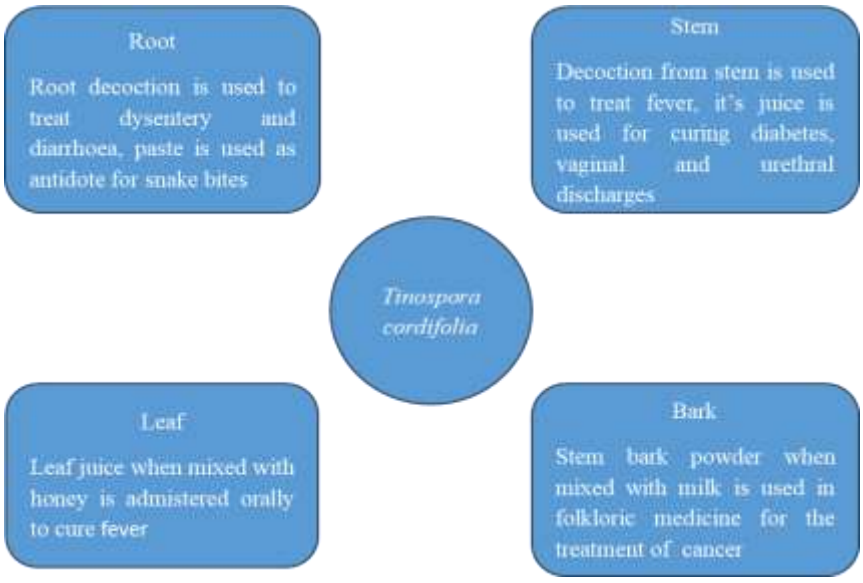

Figure 1. Schematic representation of traditional uses of *Tinospora cordifolia*

Table 1. Phytochemical constituents and the effects of major bioactive principles of *T. cordifolia*

Phytocompounds	Active principles	Effects in humans	Plant part	Reference
Alkaloids	Berberine Tinosporin Palmatine Tembetarine	Anti-cancer Neurological Infections Inflammation,	Stem, root	[14] [15] [16] [17]
Terpenoids	Tinosporide Furanoid-diterpene Sesquiterpene Tinosporaside	Respiratory Immunomodulatory Anti-inflammatory Antipyretic, antidiabetic	Whole plant	[18] [19] [20] [21]
Glycosides	Tinocordiside 18-norclerodane glucoside Tinocordifolioside Palmatosides	Neurological Neurological Anticancer activities.	Stem	[22] [23] [22] [22]
Steroids	β-sitosterol Ecdysterone	Immunomodulatory Anti-inflammatory	Stem, aerial parts	[24] [25]
Aliphatic compounds	Heptacosanol Octacosanol	Anti-inflammatory Antinociceptive	Whole plant	[26] [27]
Diterpenoid lactones	Furanolactone Clerodane derivatives	Vasorelaxant Norepinephrine induced	Whole plant	[28] [29]

2.3. Pharmacological and therapeutic aspects of *T. cordifolia*

The alcoholic extract of *T*. *cordifolia* stem and leaf parts demonstrated substantial immunomodulatory effects. At a regular dose, the extract improved α-amylase activity and bone marrow cellularity in rats. According to the studies some substances, including 11-hydroxymustakone, N-methyl-2-pyrrolidone, N-formylannonain, cordifolioside A, magnoflorine, tinocordiside, and syringing, have shown immunomodulatory effects [30]. The aqueous extract of the stem section demonstrated anti-inflammatory effect in albino rats. When given orally, it greatly reduces the acute inflammatory response to carrageenin extract [31]. The effect of the whole plant extract against CCl_4 induced changes by causing hepato-cellular changes after protein formation or bioaction, resulted in an accelerated toxification. The plant's ability to reduce free radicals and suppress lipid peroxidation makes it a potential hepatoprotective agent [32].

Anti-cancerous benefits of *T.cordifolia* have largely been researched using animal models. TCE protects testes from sub-lethal gamma radiation by increasing body weight, tissue weight, testes-to-body weight ratio, and tubular diameter in male Swiss albino mice [33]. In pre-irradiated mice, TCE reduced radiation-induced lipid peroxidation and GSH levels in testes. Pre-treatment of HeLa cells with TCE reduces cell viability, increases LDH, and decreases GSH S-transferase activity [33]. The stem methanolic extract of *T. cordifolia* (200mg/kg, i.p. daily for 5 days) significantly enhanced white blood cell count in BALB/c mice ($P<0.001$). It increased bone marrow cellularity (18.16×106/femur) and α-esterase positive cells (1423/4000), indicating stem cell maturation. The extract also significantly increased humoral immune response by increasing the number of plaque-forming cells in the spleen (1575 PFC/106 spleen cells) and circulating antibody titre (256), as well as enhancing macrophage activation (129%) [34]. Aqueous, alcoholic and chloroform extracts of *T. cordifolia* leaf extract at concentrations of 50, 100, and 200 mg/kg body weight showed significant hypoglycemic effects in diabetic rabbits [35].

Oral treatment of aqueous root extract of *T. cordifolia* to alloxan-induced diabetic rats resulted in a considerable reduction in blood glucose and brain lipids. The root extract reduces hepatic glucose-6-phosphatase, serum acid phosphatase, alkaline phosphatase, and lactate dehydrogenase levels in diabetic rats [36]. Another study demonstrated that crude ethanolic extract of *T. cordifolia* has hypoglycemic effect in alloxan-diabetic rats [37]. *T*. *cordifolia* plant decoction when effectively treated in carrageenin-induced hind paw oedema in rats, demonstrated potential anti-inflammatory properties [38]. The effectiveness of crude medication formulation incorporating *T*. *cordifolia* against *Entamoeba histolytica* was investigated. Crude extract of the plant inhibited enzyme levels of axenically cultured amoeba DNase, RNase, aldolase, alkaline phosphatase, acid phosphatase, α-amylase, and protease to variable degrees [39]. Aqueous root extract of the plant was further investigated for its hypolipidemic impact. After administering the extract at 2.5 and 5.0 g/kg body weight for 6 weeks, alloxan diabetic rats experienced significant reductions in serum and tissue cholesterol, phospholipids, and free fatty acid levels. The root extract at a dose of 5.0 g/kg body weight had the strongest hypolipidemic impact [40]. Water and ethanolic extracts of *T*. *cordifolia* stem prevented cyclophosphamide-induced immunosuppression. The ethanolic stem extract from the plant inhibited cyclophosphamide-induced anaemia. The water extract of the plant was shown to be more powerful than the other extract [41]. The medication was tested for its ability to prevent liver damage caused by the typical hepatotoxin, carbon tetra chloride in rats. *T*. *cordifolia* was found to prevent fibrous alterations and promote regeneration of parenchymal tissue, even though it exacerbated acute injury [42].

Pharmacological and clinical investigations of *T. cordifolia* was conducted to investigate its involvement in uraemia. In dogs, the water extract caused a temporary drop in blood pressure, bradycardia, and increased ventricular contraction force, as well as diuresis in rats. It drastically reduces blood urea levels in uremic dogs [43]. The non-hormonal medication minofil, combining *T*. *cordifolia* and other plant medicines, was evaluated clinically in post-menopausal women. Estriol was associated with breast soreness, nausea, and fluid retention by 22% (7 cases), but minofil had no adverse effects. Minofil is a cost-effective and side-effect-free alternative to HRT, which is still debated. It has a shorter treatment period and longer-lasting benefits [44]. Herbal mixtures along with *T. cordifolia* ingredients, has been shown to have anabolic properties. A study on the efficacy of adjuvant therapy with a multi-ingredient herbal preparation in tuberculosis patients on anti-

tubercular medications were found to be beneficial in both subjective (appetite, sense of well-being) and objective (weight, blood protein) parameters [45].

3. CONCLUSION

This review focuses on the botanical description and medicinal properties of *Tinospora cordifolia*. Scientists can use the plant's biodiversity and traditional medicinal value to identify pharmacologically active and therapeutic components for treating various ailments. It is determined that this miraculous herb has been traditionally used by numerous communities across the tribal regions of the world for the treatment of urinary, gastrointestinal, cutaneous, pulmonary, hepatic, gynaecological, inflammatory, and infectious disorders. Furthermore, traditional and local medicinal practitioners recognise the species' ability to heal allergies, tumours, and cancers. Almost all parts of the plant are being used to treat various ailments. In recent times, the old traditional practices are gradually declining extremely and under risk owing to rapid modernization, thus there is an urgent need for the documentation of such tribal species and aid to create novel ways to unlock their efficiency employed for human welfare for the future.

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RESEARCH ARTICLE

Synthesis and characterization of $BIFEO_3$ Nanoparticles for supercapacitors

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ABSTRACT

In the present study, bismuth ferrite ($BiFeO_3$) nanoparticles were synthesized by a simple and cost-effective co-precipitation method. The synthesized materials were characterized by X-ray Diffraction (XRD), Fourier Transform Infrared (FTIR) spectroscopy, and Field Emission Scanning Electron Microscopy (FE-SEM) with Energy dispersive X-ray spectrum (EDAX). Finally, the electrochemical performance was analysed using cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) analysis. From the XRD results, it was found that there was a formation of rhombohedral-structured $BiFeO_3$, and the average crystallite size of $BiFeO_3$ was calculated to be 14 nm. The FTIR analysis confirmed the existence of possible functional groups such as Bi-O & Fe-O. There was a formation of almost spherical-shaped particles in the size range of 20-40 nm as evident from FE-SEM images. The EDAX spectra of the prepared nanoparticles provided the composition of $BiFeO_3$. Finally, the electrochemical studies demonstrated that $BiFeO_3$ could be utilized as a potential electrode material for supercapacitors.

Keywords: Bismuth ferrite; co-precipitation; supercapacitors

1. INTRODUCTION

Supercapacitor namely ultracapacitors/electrochemical capacitors employ high surface area electrode materials to achieve high capacitances than conventional capacitors. They attain greater energy densities by maintaining high power density of conventional capacitors [1]. There are two charge storage mechanisms involved in supercapacitors: a) electrostatically storing the charges at the interface of the capacitor electrode as electric double-layer capacitors (EDLC) and b) Faradaically storing the charges at the electrode surface as pseudo-capacitors [2]. Pseudo-capacitors are the type of supercapacitors with metal oxide or conducting polymer electrodes as pseudo-capacitive material. The mechanism for storing charge in pseudocapacitor is a Faradaic mechanism, like oxidation-reduction reactions, involving charge transfer between electrolyte and electrode [3].

Bismuth ferrite, $BiFeO_3$ has captivated great attention in various applications because of its unique properties such as good oxygen ion conductivity, large energy density band gap, high refractive index, and dielectric conductivity. In addition, $BiFeO_3$ is non-toxic, biocompatible, & extensively used in various applications like optical materials, gas sensors, catalysts, supercapacitors, biosensors, and solid oxide fuel cells. It has been reported to be a potential electrode in electrochemical supercapacitors due to high specific capacitance and high long-term stability of charge-discharge cycles. However, the specific capacitance behavior of $BiFeO_3$ was not studied in depth [4]. In the present work, bismuth ferrite ($BiFeO_3$) nanoparticles were synthesized by a simple, cost-effective co-precipitation method. The synthesized materials were characterized by X-ray Diffraction (XRD), Fourier Transform Infrared (FTIR) spectroscopy, and Field Emission Scanning Electron Microscopy (FE-SEM) with Energy dispersive X-ray spectrum (EDAX). Finally, the electrochemical studies were carried out using cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) analysis.

2. EXPERIMENTAL METHODS

$BiFeO_3$ nanoparticles were synthesized by the chemical co-precipitation method. All the chemicals purchased were used without further purification. The synthesis process for 2 g of $BiFeO_3$ is as follows. Bismuth nitrate ($Bi(NO_3)_3.5H_2O$) and

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ferric nitrate ($Fe(NO_3)_3.9H_2O$) were chosen as starting precursors. 3.101 g of $Bi(NO_3)_3.5H_2O$ was dissolved in 6 mL of concentrated nitric acid (HNO_3). This solution was then diluted with 40 mL of double-distilled water. Later 2.5829 g of $Fe(NO_3)_3.9H_2O$ was dissolved in 40 mL of water and dropped into the bismuth nitrate solution under constant stirring. Next 0.7672 g of sodium hydroxide (NaOH) was dissolved in 20 mL of distilled water separately and added drop by drop into the above mixture of precursors. The initial pH of the solution was found to be 2. Ammonia solution was added to bring up the value of pH to 7. A brown color precipitate was formed under constant stirring for 2 hours. The obtained precipitate was centrifuged and dried in a muffle furnace at 120°C for 2 hours. Thus obtained powder was calcinated at 500°C in a muffle furnace for 2 hours. The prepared material was subjected to various characterization techniques like XRD, SEM, FTIR, and EDAX respectively. The electrochemical performance was studied using cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) analysis. The working electrode for studying the electrochemical performance was prepared by mixing the active material, carbon black, PVDF (polyvinylidenefluoride) in the weight ratio of 80:10:10 using NMP (N-methyl 2 pyrrolidione) as a solvent to form a slurry. Then 10 µL of slurry was coated onto a stainless steel electrode of area 1x1 cm^2. Finally, the loaded active mass was calculated to be 0.8 mg. The coated slurry was air dried at 50°C overnight. The cyclic voltammetry, charge–discharge, and electrochemical impedance analysis were carried out using an SP-150 BIO-LOGIC science workstation. Three-electrode configuration was used for electrochemical characterization utilizing platinum as a counter electrode, and Hg/HgO was used as the reference electrode.

3. RESULTS AND DISCUSSION

3.1. X-ray Diffraction

Figure 1 shows the XRD pattern of $BiFeO_3$ nanoparticles synthesized from bismuth nitrate and ferric nitrate using the co-precipitation method at pH- 7 and calcinated at 500°C. The XRD peaks are sharp confirming the crystalline nature of $BiFeO_3$. The diffraction peaks observed at 2θ of 22.480°, 32.117°, 39.559°, 45.890°, 51.526°, 57.112°, 67.178°, 71.574°, and 75.921 corresponds to (100), (110), (111), (200), (210), (211), (220), (300), and (310) planes of $BiFeO_3$. All the diffraction peaks displayed strong similarity with the reported JCPDS No. 72-2112. The study reveals the crystalline structure as the rhombohedral system with lattice parameters a = b = c = 3.952 Å. The formation of rhombohedral-structured $BiFeO_3$ with an additional peak of Bi_2O_3 was detected using XRD analysis.

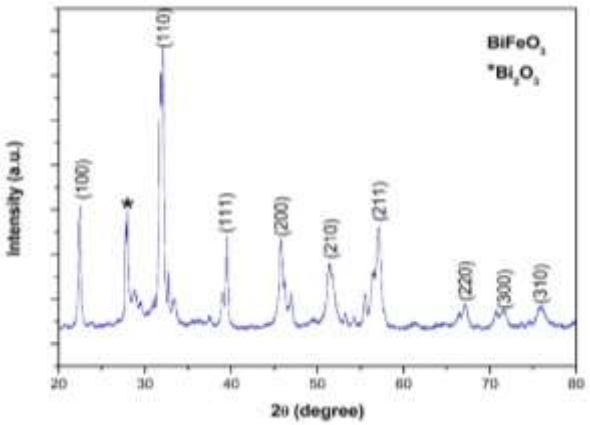

Figure 1. XRD Pattern of bismuth ferrite nanoparticles

The crystallite size (D) of the synthesized nanomaterials is calculated using Scherer's formula.

$$D = K\lambda / \beta\cos\theta \quad (nm) \qquad (1)$$

where the K-shape factor is taken as 0.94, λ-wavelength of the incident beam (CuKα radiation), D-mean crystallite size, β-full width at half maximum, and θ-Bragg's angle. The average crystallite size of $BiFeO_3$ is found to be 14 nm.

The lattice density (ρ) of the $BiFeO_3$ nanostructure was estimated using the equation given below

$$\rho = ZM/Na^3 \quad (g/m^3) \qquad (2)$$

where Z is the number of moles per unit cell, M is the molecular weight of $BiFeO_3$, N is Avogadro's number ($6.022x10^{23}\ mol^{-1}$), and a^3 is the volume of the unit cell. The calculated of $BiFeO_3$ lattice density (ρ) was found to be $0.2816 \times 10^3\ kg/m^3$.

The surface area (S) of prepared $BiFeO_3$ by co-precipitation synthesis is calculated using the formula

$$S = 6/\rho D \quad (m^2/g) \qquad (3)$$

where ρ is the lattice density in g/m^2, D is the crystallite size in nm. The surface area was found to be 152 m^2/kg.

3.2. Fourier Transform Infrared Spectroscopy

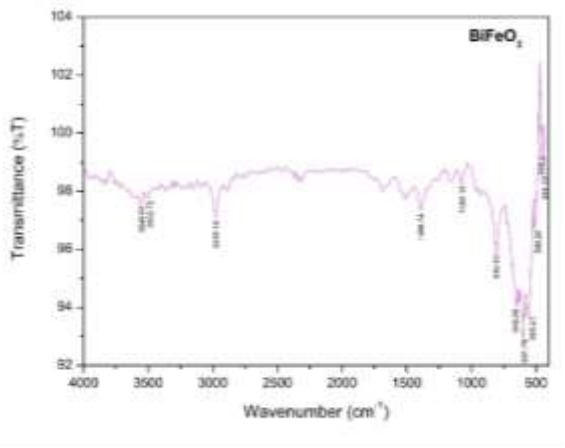

Figure 2. FTIR spectrum of $BiFeO_3$

Figure 2 shows the FTIR spectrum of $BiFeO_3$. The broad absorption bands located between 600 and 400 cm^{-1} are due to the stretching and bending vibrations of Fe–O [5]. The $BiFeO_3$ has a Fe-O absorption peak at 810 cm^{-1}[6]. The peaks at 1080 cm^{-1} are attributed to the vibration of the Bi-O bond [6]. The FTIR analysis confirmed the presence of functional groups in $BiFeO_3$

3.3. Morphological analysis

The morphological features of synthesized material such as particle size distribution were observed using a field emission scanning electron microscopy (FE-SEM), equipped with an energy-dispersive X-ray spectrometer (EDAX). Figure 3 depicts the FE-SEM micrographs of the $BiFeO_3$ nanoparticles prepared by the chemical co-precipitation method. The FE-SEM images clearly show the morphology of $BiFeO_3$ to be more or less spherical in shape with a size range of 20 - 40 nm with slight agglomeration.

The EDAX analysis of the synthesized sample is illustrated in Figure 4. This pattern confirms that the elements in the samples are Bi, Fe, and O.

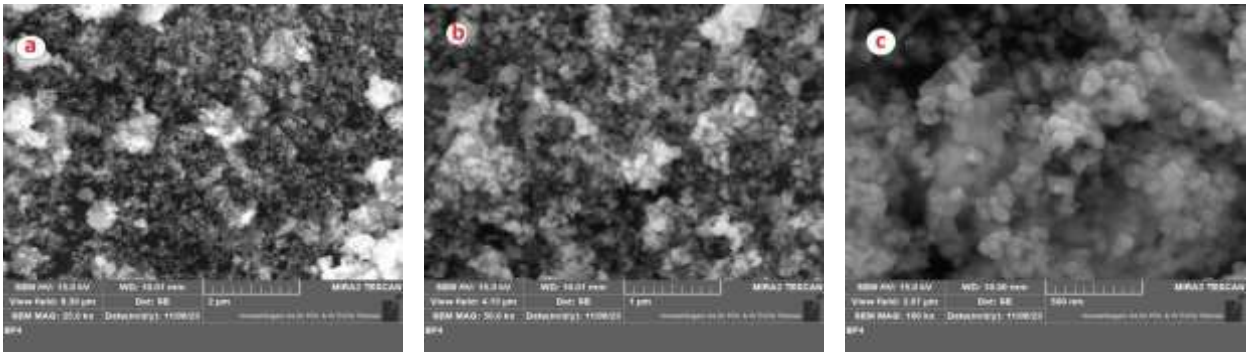

Figure 3. Field emission scanning electron microscopy

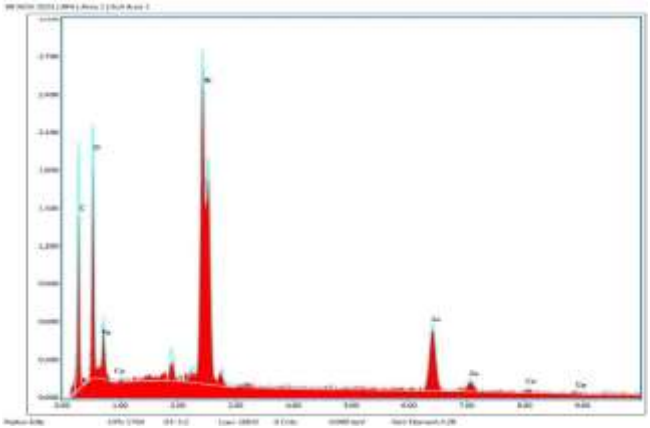

Figure 4. Energy dispersive X-ray spectroscopy (EDAX)

3.4. Electrochemical studies

3.4.1. Cyclic voltammetry

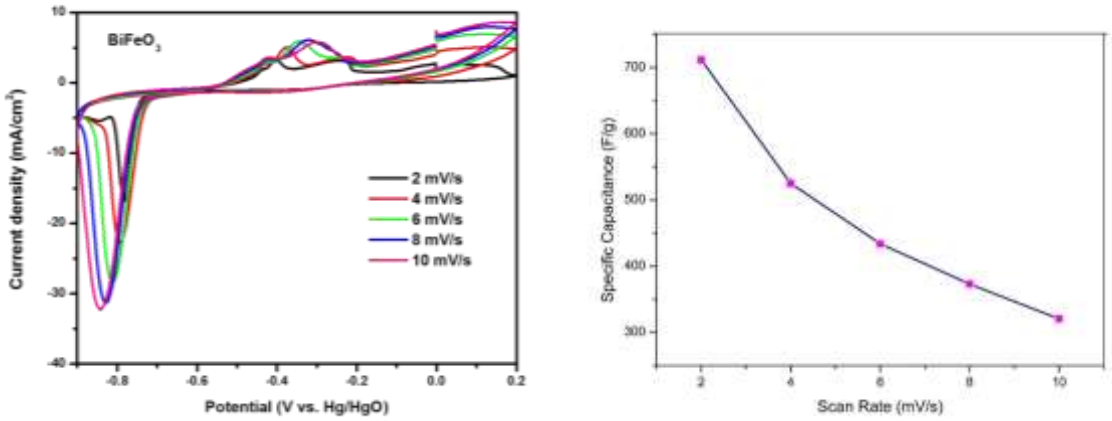

Figure 5. CV curves of $BiFeO_3$ and the calculated specific capacitance of $BiFeO_3$ at various scan rates

The cyclic voltammetry (CV) is the basic electrochemical analysis of the material where the current is recorded by sweeping the potential back and forth (from positive to negative and negative to positive) between the chosen limits. The information obtained from CV can be used to learn about the electrochemical behavior of the material. The potential at which the material is oxidized and reduced can be found.

Figure 5 shows the CV curves of $BiFeO_3$ in the potential range from -1.0 to 0.2 V. There is a pair of redox peaks observed which elucidates the pseudo capacitive behavior and these redox peaks are due to the oxidation and reduction reactions take place in the material. The CV curves revealed an oxidation peak at -0.3 V and a reduction peak at -0.87 V during the anodic/cathodic scan. The reduction peaks are due to the reduction of Bi (III) to Bi-metal and the oxidation peak is due to the oxidation of Bi metal to Bi (III), respectively.

The specific capacitance of the material is calculated using the following formula:

$$C_{sp} = \frac{\int I\, dv}{2 \times \vartheta \times m \times \Delta V} \qquad (4)$$

where ΔV represents the potential window (V), m stands for the mass of electroactive material (mg), and v for scan rate (mV/s), while ∫IdV stands for the area under the CV curve. The estimated specific capacitance (Csp) values of $BiFeO_3$ were 711, 525, 433, 373, and 320 Fg^{-1} at 2, 4, 6, 8, and 10 mVs^{-1} respectively and also provided in figure 5. The capacitance of the material is found to be decreased with increasing scan/sweep rates and it was due to the number of active sites that actively participated in the redox reactions was low at higher scan rates.

3.4.2. Charge–discharge studies

The galvanostatic charge-discharge (GCD) profile recorded at various current densities ranging from 2.0 to 5.0 $mAcm^{-2}$ is shown in Figure 6. A nonlinear discharge curve is seen at all current densities that indicate the occurrence of the electrochemical redox process and agrees with the CV results. As seen from the figure, a higher discharge time is observed for the material at low current density and the discharge time decreases with increasing current density.

The specific capacitance of the material can be calculated using the following formula:

$$C_{sp} = \frac{I\,\Delta t}{m\Delta v} \qquad (5)$$

where Δv represents the potential window, I stands for current density (mA/g), m stands for the mass of electroactive material (mg), and Δt stands for discharge time (s). From GCD studies, Csp values of $BiFeO_3$ were calculated to be 3161, 2077, and 807 Fg^{-1} at the current density of 2, 2.5, and 5 $mAcm^{-2}$ respectively. The specific capacitance is larger at lower current density and decreases with increasing current density. It is worth mentioning that the synthesized material exhibited reversible electron transfers, which may account for its excellent electrochemical performance. Also from the figure, the Csp values decreased with an increase in current

density because, at high currents, only the outer surface of the electroactive material contributed to the redox reaction to proceed. Hence the specific capacitance values decreased upon increasing the current density.

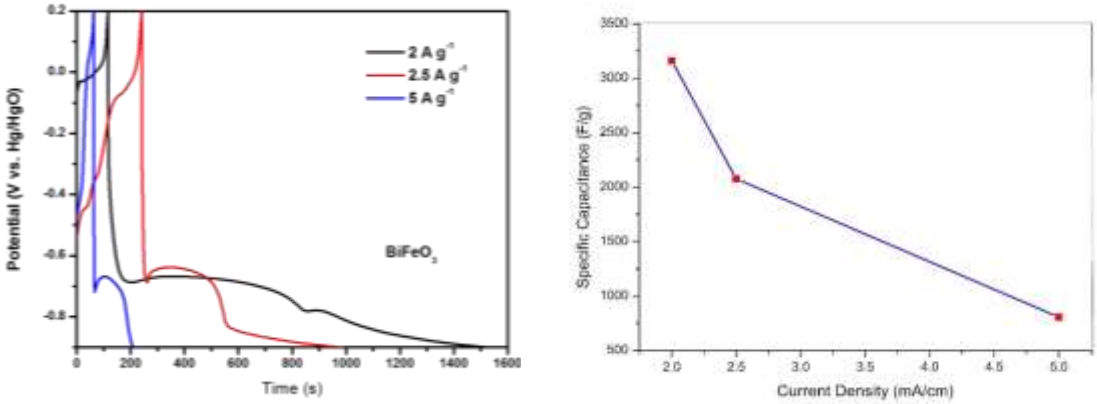

Figure 6. Galvanostatic charge-discharge curve at various current densities and specific Capacitance at various current density

4. CONCLUSION

$BiFeO_3$ powders were successfully synthesized through the chemical co-precipitation method. Structural and morphological analysis was carried out by XRD, FTIR, FE-SEM, and EDAX. The formation of rhombohedral-structured $BiFeO_3$ with an additional peak of Bi_2O_3 was detected using XRD analysis. Crystallite sizes deduced from XRD analysis were found to be 14 nm. Possible functional groups such as Bi-O & Fe-O were confirmed from FTIR. There was a formation of more or less spherically shaped particles in the size range of 20-40 nm. The synthesized $BiFeO_3$ exhibited a specific capacitance of 711 Fg^{-1} at 2 mVs^{-1} by CV studies and 807 Fg^{-1} at 5 $mAcm^{-2}$ current density by GCD. Hence $BiFeO_3$ could be utilized as a potential electrode material for supercapacitors.

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RESEARCH ARTICLE

A comparative phytochemical investigation on selected Macroalgae in Thikkodi Coast, Kerala

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ABSTRACT

Marine algae are morphologically diverse group of plants which can be regarded as primary producers. They are the sources of vitamins, mineral, proteins and antioxidants. Marine algae is an interesting group of algae which has a wide range of biological activities. They are chemically unique in nature which makes them an ideal substance for preparation of anticancer drugs. The phytochemistry of plants are gaining attention recently across the world. The Phytochemical screening tests of twelve different chemicals compounds (alkaloids, terpenoids, tannins, saponins, flavonoids, phenols, coumarins, proteins, carbohydrates, glycosides) were done in five algal species collected from Thikkodi Coast, Kerala. The results show that the flavonoids and tannins are present all the selected samples. The present research work has focussed on the comparative phytochemical profiling of the selected seaweeds in two different solvents.

Keywords: phytochemical, algae, antioxidant, drugs, solvents

1. INTRODUCTION

Recently Extensive studies on secondary metabolites have been carried out as it's a great source of medicinal agents. The Seaweeds are the major part of the marine ecosystem. They are highly nutritive in nature. They mostly grow on hard substrate areas of intertidal region, which are regularly exposed during low tides and submerged during high tides. From Ancient times the seaweeds have been used as medicine and food. The algae majorly contribute to the half of the oxygen produced in earth. Hence, it's really important to pay attention to analyse the seaweed diversity and make use of them for a sustainable environment. Ecological and biological importance of the macro algal communities of near-shore coastal ecosystems are studied worldwide [2]. Macro algae play a salient role in structuring the marine ecosystem for a variety of organisms and influences them in different stages of their lifecycle. The marine algae are also called as seaweeds. They can be divided into three, namely green algae, Red algae and Brown algae (or Chlorophyta, Rhodophyta and Phaeophyta respectively)

Phytochemistry is the study of chemicals produced by the plants. These secondary metabolites are produced as a measure of self defence against insects, pest, pathogens. The phytochemicals from the algae are extensively used in different industries such as textile, food, confectionary pharmaceutical, diary and paper mostly as gelling, stabilizing, thickening dyeing agents. For a long time algal chemistry from terrestrial to marine or freshwater bodies has fascinated numerous investigators to develop new drugs in the nutraceutical and pharmaceutical industries [10].

Research concern has greatly enhanced the marine life and their amazing secondary metabolites started to be used for their strong therapeutic activities in the last decades. Due to the adaptive nature of the algae in different harsh type of environments, they may generate numerous secondary metabolites with complete structural cores circumscribe alkaloids, cyclic peptides, polysaccharides, sterols, glycerol, quinones. Moreover, algal organisms represent a rich source of new primary and secondary metabolites. These compounds are biologically active which can be exclusively used in pharmaceutical industry. Therefore, recently a new trend has been arisen to isolate novel bioactive compounds and constituents from edible seaweeds [7]. Phytochemical analysis of seaweeds can help the

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manufactures for the identification and selection of raw materials for drug production [1]. The secondary metabolites have always attracted the interest of biochemists because of the diversity as compared with that of the higher plants. Here the present study is intended to evaluate the phytochemical screening in the five of the seaweeds collected from Thikkodi Coast, Kerala, India.

2. MATERIALS AND METHODS

2.1. Collection of Marine algae

The macro algae were collected from Thikkodi Coast of Kozhikode district, Kerala. Immediately after collection, the collected samples were washed to remove the epiphytes, other organisms or any extraneous matter. After subsequent washing the algal samples were shade dried for about a month. The shade dried seaweeds were partially powdered using the mixer and stored in air tight container for further studies.

2.2. Preparation of Extracts

The Phytochemical screening was done by using the Soxhlet apparatus. 30 g of fine powder was packed separately in No.1 Whatman filter paper and placed in Soxhlet apparatus along with solvent Chloroform and Methanol on basis of polarity. The residues were collected and dried at room temperature 30◦ C after which yield was weighed and then performed to activity.

2.3. Phytochemical Screening

The phytochemical screening of different algal extracts was assessed by Harborne method (1973) [5]. General reactions in these analyses revealed the presence or absence of these compounds in the algal extracts tested. Preliminary phytochemical screening of twelve different chemical compounds (alkaloids, carbohydrates, proteins, coumarins, flavonoids, steroids, glycosides, tannins, saponins, anthraquinones, glycosides, phenols) were tested in two different extracts. In order to detect the chemical composition and to establish the algal profile different qualitative chemical tests were performed.

Test for carbohydrates

2 drops of Molish reagent was added to an aqueous hydrochloric acid solution to the extract add 2ml of concentrated sulphuric acid was added by the sides of the test tube. Formation of reddish violet ring at the junction of two liquids indicates the presence of carbohydrates.

Test for proteins

To the extract ,1 ml of 40% sodium hydroxide solution and 2 drops of 1% Copper sulphate solution were added. Appearance of violet color indicates the presence of proteins.

Test for Steroids

To the extract ,2ml of Chloroform and 1ml of concentrated Sulphuric acid was added. Formation of Red colour indicates the presence of steroids.

Test for Coumarins

To the extract 1ml of 10% NaOH was added. Formation of yellow colour indicates the presence of Coumarins

Test for alkaloids

1 ml of 1% HCl was added to the 2 ml of extract in a test tube and was treated with few drops of Mayer's reagent. The presence of alkaloids was indicated by the appearance of creamy white precipitate.

Test for saponins: Frothing test

2 ml of the extract was shaken vigorously with 5 ml of distilled water to obtain stable persistent foam. Formation of frothy solution indicates the presence of saponins

Test for glycosides

2 ml of 50% H_2SO_4 was added to the 2 ml of extract in a boiling tube. Then the mixture is heated in a boiling water bath for 5 min .10 ml of Fehling's solution was added and boiled. Formation of brick red precipitate indicates the presence of glycosides.

Test for terpenoids

To the extract ,2 ml of $CHCl_3$ was added in a test tube and then 3 ml of concentrated H_2SO_4 was added carefully along the wall of the test tube to form a layer. A reddish-brown colour formed on the interface confirmed the presence of terpenoids.

Test for tannins

To the extract ,1 ml of distilled water and 1-2 drops of ferric chloride solution was added. Brownish green or blue -black colouration indicates the presence of tannins.

Test for anthraquinones

2 ml of extract was mixed with benzene and 1 ml of 10% Ammonia solution was added. The presence of pink, red or violet colour indicates the presence of anthraquinones.

Test for phenolic groups

To 1 ml of extract, add 2 ml of distilled water followed by few drops of 10% Ferric chloride. The formation of blue-black colour indicates the presence of phenolic groups.

Test for flavonoids

A few drops of 1% NH3 solution was added to 2 ml of extract in a test tube. Formation of yellow colouration indicates the presence of flavonoids.

3. RESULTS AND DISCUSSION

Seaweeds are the resource material for structurally unique natural products with pharmacological and biological activities. Marine pharmacognosy is a branch of terrestrial pharmacognosy which investigates the medically dominant plants and animal in marine ecosystem. The 79% of earth's surface is covered by water. The research into the chemistry of marine organisms is moreover unexplored. The selected solvents both chloroform and methanol have shown good results. Flavonoids and tannins are found to be present in all the samples both in chloroform and methanol extracts. Flavonoids in human diet may reduce the risk of various cancers, as well as preventing menopausal symptoms. It's a potent water soluble antioxidants and free radical scavengers prevent oxidative cell damage and have strong anticancer activity. They show antiallergic, anti-inflammatory, antimicrobial and anti-cancer activity [3,4,6,11]. Tannins are known to possess general antimicrobial and antioxidant activities [9]. Flavonoids are hydroxylated phenolic substances known to be synthesized by plants in response to microbial infection and they have been found to be antimicrobial substances against wide array of microorganisms in vitro. Flavonoids, the major group of phenolic compounds reported for their antimicrobial and antiviral activity. Tannins have antibacterial activity, forming complex compounds with proteins through hydrogen bonds, when these are formed between tannins and proteins altering the protein structures and disrupting the bacterial metabolism. Tannins inhibit the reverse transcriptase enzyme, the DNA topoisomerase, and also cell wall polypeptides, so that the cell walls imperfections cause bacterial cell's lysis and eventually their death, due to osmotic and physical pressure [8]. Tannins are produced by algae as a form of defence against microbes. Both the solvents can dissolve the most of the organic compounds in the selected samples. The bioactive compounds found from the marine algae are shown in the tables 1 ad 2.

Table 1. Table showing the phytochemical studies in Chloroform extract

PHYTOCHEMICALS	*C. chemnitzia*	*C. sertularioides*	*G. corticata*	*P. tetrastromatica*	*S. polycystum*
Alkaloids	++	++	++	+	-
Phenols	++	+	-	+	+
Flavonoids	++	++	++	++	+
Anthraquinones	-	-	-	-	-
Tannins	+	+	+	+	++
Coumarins	-	-	+	+	-
Carbohydrates	+	-	+	+	+
Saponins	+	-	-	+	+
Steroids	-	+	+	-	-
Proteins	+	+	+	+	+
Glycosides	+	+	+	-	-
Terpenoids	-	++	++	+	+

Table 2. Table showing the phytochemical studies in Methanol extract

PHYTOCHEMICALS	*C. chemnitzia*	*C. sertularioides*	*G. corticata*	*P. tetrastromatica*	*S. polycystum*
Alkaloids	+	+	++	+	-
Phenols	++	+	-	+	-
Flavonoids	++	++	++	++	+
Anthraquinones	-	-	-	-	+
Tannins	++	+	-	++	+
Coumarins	-	-	+	+	-
Carbohydrates	+	-	++	++	+
Saponins	-	-	-	+	+
Steroids	+	+	-	+	-
Proteins	+	+	+	+	+
Glycosides	+	+	+	-	-
Terpenoids	++	++	-	++	++

-: Absent, + : Present, ++ : Intensly Present

4. CONCLUSION

The development of Science and technology has given a better understanding of the diseases, changes in disease patterns etc. The macroalgae has the potential to be a source material of the bioactive compounds. The identification of these bioactive compounds is important in drug designing. It's necessary to carry out research in this field so that we can draw out an accurate information for the development and discovery of novel drugs. Phytochemicals are solemnly embarking on research activities involving the extraction of the organic compounds. Some of these compounds have the ability to suppress the cancer cells by promoting the cell cycle inhibition and apoptosis. The demand on naturally derived compounds is increasing day by day, so as to replace the synthetic ones.

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