

A Review of Machine Learning and Deep Learning Approaches for Tulsi Classification in Health Monitoring and Species Identification

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Abstract—This review explores the effectiveness of Machine Learning (ML) techniques in identifying and categorizing diseases affecting Tulsi (*Ocimum sanctum*) leaves. Tulsi, or holy basil, is renowned for its medicinal properties, including its ability to protect against infections and diseases of the liver, skin, kidney, and more. Its antioxidant properties make it beneficial for heart health and diabetes management. Deep Learning (DL) algorithms, such as Convolutional Neural Networks (CNNs) like InceptionV3 and ResNet, have been used to identify and categorize various species of the Tulsi plant. This technology automates disease detection and classification, enabling early diagnosis and effective treatment. The paper reviews various ML algorithms used for similar tasks and their accuracy, aiming to unlock Tulsi's potential as a potent natural remedy.

Index Terms— Tulsi, *Ocimum sanctum*, Machine Learning, Deep Learning, disease detection, disease classification, Medicinal Plant.

I. INTRODUCTION

Tulsi (*Ocimum sanctum*), or holy basil, is revered in traditional medicine, especially Ayurveda, for its medicinal benefits, earning it the title "The Queen of Herbs." [4] for her restorative and spiritual properties. Its ability to combat various infections and diseases has made it the subject of extensive research. The unique virtues of Tulsi are highlighted in a Sanskrit verse: "तुलस्यास्ति विशेषेण गुणो नान्योऽस्ति तत्त्वतः। निर्विषेषंतुलस्याहुः सर्व रोग निवारणम्॥" which translates to "There is no other herb like Tulsi, it is unparalleled in its ability to cure all diseases." Over the years, Tulsi has been recognized for its therapeutic benefits, including its role in protecting the body against infections and diseases of the liver, skin, kidney, and more.[4] Tulsi's medicinal properties include regulating blood pressure, managing diabetes, and treating fever, skin issues, heart disease, and respiratory problems. It is vulnerable to diseases like leaf rust, powdery mildew, and Downy mildew[5] prompting research using ML for disease detection and classification. The following are the objectives focused by reviewing the present research.

- Analyze existing methods for Tulsi disease and leaf classification, adapting for limited datasets.
- Investigate different algorithms for early detection and prevention of Tulsi diseases.
- Evaluate transfer learning and hybrid models for accurate Tulsi disease classification with limited data.
- Review ML and DL algorithms to aid new researchers and health workers in similar tasks.

II. LITERATURE REVIEW

Yigal Cohen warns of the global threat of basil downy mildew from Uganda, spreading rapidly and infecting sweet basil crops. K. Bharathan developed an automated system that identifies Tulsi leaves with 95% accuracy by extracting color and texture features. [3] J. Liu's ten-layer CNN with sample augmentation classifies plant leaves with 87.92% accuracy on the Flavia leaf database. Gittaly Dhingra's model for basil leaf diseases uses a "survival of the fittest" strategy, achieving 95.73% accuracy. [11] Muhammad Azfar Firdaus Azlah stresses the need for quality leaf databases for accurate plant classification, using neural networks like ANN, PNN, CNN, KNN, and SVM. [25] Amy Malek praises Tulsi as the "Queen of Herbs" in Ayurveda, highlighting its health benefits and Organic India's commitment to regenerative farming. [4]

Jeffrey R. Standish provides a diagnostic guide for basil downy mildew, covering symptoms, taxonomy, pathogen isolation, PCR identification, pathogenicity tests, and global distribution. [5] Massimo Brambilla analyzed basil plants with varying nitrogen levels using an RGB sensor and an optical leaf meter. While the RGB sensor correlated with nitrogen levels in univariate analysis, it lagged behind the leaf meter at higher nitrogen levels, indicating potential for improvement with more data. [8] Snježana Topolovec explores *Peronospora belbahrii*, a destructive basil downy mildew pseudofungus originating from Africa and spreading globally through seed transmission. [10] Pushkara Sharma's AI-based plant leaf disease detection and classification system achieves 98% accuracy with CNN, promising to enhance crop yield and quality through improved disease detection and remedy application. [15] Raisa Akter proposes a three-layer CNN for automated medicinal plant classification, reaching 71.3% accuracy. This system aids in identifying beneficial plant species, enabling easier recognition and utilization for medicinal purposes. [18] Muneer introduces a system using SVM and DLNN classifiers to classify Malaysian herbs with 74.63% and 93% accuracies, respectively. Integrated into a mobile app, it aids pharmacists and botanists with fast processing times. [20]

Ümit Atila proposes using EfficientNet DL for plant leaf disease classification, achieving up to 99.97% accuracy and 99.39% precision with B5 and B4 models on the Plant Village dataset. This demonstrates DL's effectiveness in automated plant disease diagnosis without manual feature extraction. [24] Jagadeesh Basavaiah improves tomato disease identification using multiple features and random forest/decision tree classifiers, achieving 94% and 90% accuracy, respectively. This aims to enhance agricultural productivity by preventing crop losses. [28] Aditya Karlekar introduces a two-module computer vision approach for accurate plant disease diagnosis, achieving 98.14% accuracy for soybean diseases using the SoyNet DL CNN. This method outperforms hand-crafted and popular CNN models, promising to enhance crop yield and combat plant diseases to meet future food demands. [31] Andres F. Salcedo emphasizes the threat of downy mildews to global crops and advocates for molecular methods in early-stage identification. His research offers a guide for optimal diagnostic approaches to combat these diseases. [13] Sunil Tyagi's study analyzes the journal "Tulsi Prajna" from 2016 to 2020, showing a growing trend in contributions. During this period, 121 papers were published, mostly articles. Single authors, particularly Acarya Mahaprajna, were the most frequent contributors. There was a notable increase in citations in 2019, indicating the impact and relevance of research during that period. [21] Jinzhu Lu emphasizes the threat of plant diseases to crop production and the importance of accurate detection. The review focuses on deep learning methods, especially Convolutional Neural Networks (CNNs). [26] Murat Koklu achieved a 97.60% success rate in classifying grapevine leaves using DL, with data augmentation and feature selection enhancing the model's performance. Mrs. Sheetal S. Patil emphasized Tulsi's medicinal importance during COVID-19, proposing a CNN model for accurate disease detection, achieving 75% accuracy. [9] Himanshu Chanyal's work focuses on using ML and DL algorithms to automatically classify medicinal plants based on leaf images, aiming for cost-effective and accurate early disease detection. [12] Deepak Mane proposes a hybrid CNN-SVM model for predicting basil plant leaf diseases, achieving an impressive 95.02% accuracy rate. This model combines the strengths of CNN for training and SVM for classification, outperforming traditional methods, especially in balanced datasets. Early detection is crucial for preventing significant losses in medicinal plants due to diseases. [1] V. Sathiya introduces a CNN-based approach to automate disease identification in Basil and Mint leaves, achieving validation accuracies of 77.55% and 70.89%, respectively. This study, leveraging the Inception V3 model with Adam Optimizer, advances plant disease detection, offering potential benefits for enhancing crop yield in agriculture, which is vital to India's economy. [6] Chittabarni Sarkar underscores leaf disease detection's

economic significance, advocating for multispectral imaging and ML/DL models. Their study evaluates SVM, Random Forest, CNN, VGG, and ResNet models, emphasizing F1 score and precision for efficient classifier selection. [14]

S. Kavitha's study proposes a vision-based DL model with 98.3% accuracy for identifying medicinal plants in India, using the MobileNet DL model on a cloud platform. The model allows real-time leaf identification via a mobile app, demonstrating potential in botany and machine vision.[17] D. Bhanu Prakash's study evaluates ML models for plant leaf identification, with Quadratic Discriminant Analysis (QDA) performing best at 93% accuracy.[19] Demilie, W.B., emphasizes the importance of early and accurate plant disease detection to reduce crop damage. Automated image processing methods, including DL and ML techniques like CNNs, offer effective solutions for disease detection and classification in agriculture.[22] Biplob Dey's study compares seven DL algorithms for automated medicinal plant identification, finding DenseNet201 to be the best-performing model with 99.64% accuracy..[27]

Sachin Jain's study presents a DL-based approach for mango leaf disease classification, achieving 97.7% accuracy. Customized support vector machines (SVM) and a hybrid SVM and stochastic gradient descent (SGD) method are used for effective image segmentation and disease classification, showing promise for early disease detection and diagnosis.[29] Manjot Kaur's study assesses stacking classifier algorithms for predicting tulsi leaf diseases, identifying model B with 98.25% average accuracy as the most effective for early diagnosis.. [2] Naeem Ullah highlights the importance of automated systems in detecting and diagnosing plant diseases to enable early intervention and prevent widespread transmission.

III. TYPES OF HEALTHY TULSI AND ITS DISEASES

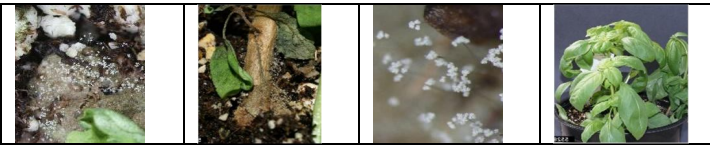
A. Types of healthy Tulsi: Table I: Types of Healthy Tulsi Images

Sr. No	Image	Botanical name	Region	Medicinal Uses
1	 Rama Tulsi [32]	Ocimum Sanctum	India	Respiratory disorders, fever, asthma, lung disorders
2	 Krishna Tulsi [32]	Ocimum tenuiflorum	India	Cough, cold, skin disorders, insect bites
3	 Amrita Tulsi [32]	Ocimum tenuiflorum	India	Stress, anxiety, inflammation, immune system support
4	 Vana Tulsi [32]	Ocimum Gratissum	India	Adaptogen, immunity booster, respiratory disorders
5	 Sweet Basil [32]	Ocimum Basilium	Europe, North America	Digestive disorders, anti-inflammatory, antioxidant
6	 Thai Basil [32]	Ocimum Thyriflora	Southeast Asia, Thailand	Digestive aid, anti-inflammatory, antibacterial
7	 Purple Basil [32]	Ocimum Basilicum	Europe, North America	Antioxidant, anti-inflammatory, anti-cancer properties

8	 Lemon Basil [32]	Ocimum Citriodorum	Europe, North America	Digestive aid, stress relief, fever reducer
9	 Vietnamese Basil [32]	Ocimum Cinnamon	Vietnam, Southeast Asia	Aromatic, culinary uses, insect repellent
10	 American Basil [32]	Ocimum Americanum	North America	Culinary herb, mild medicinal uses
11	 African Blue Basil [32]	Ocimum Kilimandscharicum	Africa	Ornamental plant, mild medicinal uses
12	 Italian Genovese Basil [32]	Ocimum Basilicum	Italy, Europe	Culinary herb, mild medicinal uses

The table presents healthy Tulsi images, botanical names, regions, and medical uses. Tulsi, or holy basil, is valued in Ayurveda for adaptogenic and antimicrobial properties, aiding in stress protection and sanitation.

IV. TYPES OF DISEASES IN TULSI WITH IMAGES

1. Cercospora leaf spot <i>Cercospora ocimicola</i> Symptoms: Circular to irregular dark spots on leaves with light centers Cause: Fungus 2. Downy mildew <i>Peronospora belbahrii</i> Symptoms: Yellowing leaves; discoloration often begins around middle vein and spreads outwards; gray fuzzy or downy growth on lower surface of the leaves; brown to black angular necrotic patches on the plant. Cause: Fungus 3. Gray Mold <i>Botrytis cinerea</i> Symptoms: Dense, brown to Gray fuzzy growth on stems and leaves and fallen plant debris; leaves dying and dropping from plant; severe lesions on stem may cause plant death. Cause: Fungus 4. Leaf spot <i>Pseudomonas cichorii</i> Symptoms: Angular or irregular brown or black water-soaked spots on leaves; streaks on stems. Cause: Bacteria	 (A) (B) (C) (D) Figure 1: Types of Tulsi diseases-I- Leaf Spot  (A) (B) (C) (D) Figure 2: Types of Tulsi diseases-II- Downy mildew  (A) (B) (C) (D) Figure 3: Types of Tulsi diseases-III- Gray Mold  (A) (B) (C) (D) Figure 4: Types of Tulsi diseases-IV- Leaf Spot
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Tulsi Cercospora leaf spot, caused by *Cercospora ocimicola*, appears as dark spots with light centers on leaves, common in warm, humid climates. Control methods include sanitation, fungicidal sprays, avoiding overhead

irrigation, crop rotation, and planting resistant varieties. [Fig1]. Tulsi Downy mildew, caused by *Peronospora belbahrii*, is characterized by yellowing leaves with gray fuzzy growth underneath and angular necrotic patches. Control methods include fungicidal sprays and improving air circulation. [Fig2] Tulsi Gray Mold, caused by *Botrytis cinerea*, results in brown to gray fuzzy growth on stems and leaves, leading to leaf death and stem lesions. Control involves removing infected parts, improving air circulation, and avoiding overhead watering. [Fig3]. Tulsi Leaf spot caused by *Pseudomonas cichorii* shows as angular brown or black spots on leaves and stems. Management includes sanitation, copper-based fungicides, and better air circulation. [Fig4].

TABLE II: COMPARATIVE ANALYSIS

Sr No	Name of the Paper	First Author	Year	Algorithm/Model	Accuracy	References
1	Plant Leaf Classification Based on Deep Learning	J. Liu	2018	CNN with 10 Layers	87.92	[23]
2	Basil leaves disease classification and identification by incorporating survival of fittest approach	Dhingra, G.	2019		94.73	[11]
3	Classification of plant leaf diseases using ML and Image Preprocessing Techniques	P. Sharma	2020	Logistic Regression	66.4	[15]
				KNN	54.5	
				SVM	53.4	
				CNN	98	
4	CNN-based Leaf Image Classification for Bangladeshi Medicinal Plant Recognition	R. Akter	2020	SVM	20.36	[18]
				K Nearest Neighbour	28.44	
				Random Forest	47.25	
				2 Layer	62.8	
				3 Layer	66.92	
				4 Layer	69.33	
				3 Layer (with dropout+ gaussian noise + batch normalization)	71.3	
5	Efficient and Automated Herbs Classification Approach Based on Shape and Texture Features using Deep Learning	A. Muneer	2020	SVM (RBF Kernel)	74.63	[20]
				DLNN	93	
6	Plant leaf disease classification using EfficientNet deep learning model	Ümit Atila	2020	EfficientNet	99.91	[24]
7	Tomato Leaf Disease Classification using Multiple Feature Extraction Techniques	Basavaiah	2020	Decision tree	90	[28]
				Random forest	94	
8	SoyNet: Soybean leaf diseases classification	Aditya Karlekar	2020	CNN	98	[31]
9	A CNN-SVM study based on selected deep features for grapevine leaves classification	Murat Koklu	2021	MobileNet	97	[30]
				SVM	93	
10	Tulsi Leaf Disease Detection using CNN	S. S. Patil	2022	CNN	0.75	[9]
11	Basil plant leaf disease detection using amalgam based deep learning models	Deepak Mane	2023	CNN	89.84	[1]
				CNN+KNN	94.19	
				CNN+SVM Poly	94.19	
				CNN+SVM Sigmoid	94.6	
				CNN+SVM rbf	95.02	
				CNN+SVM linear	43.56	
				Proposed Hybrid Model	95.02	
12	Plant Disease Classification of Basil and Mint Leaves using Convolutional Neural Networks	Sathiya, V.	2023	CNN-Inception V3	77.55	[6]
13	Medicinal Plant Identification in Real-Time Using Deep Learning Model	Kavitha, S.	2023	MobileNet	97	[17]
14	Mango Leaf disease Classification using deep learning Hybrid Model	S. Jain and P. Jaidka	2023	Hybrid Model(SVGD)	0.996	[29]
				SVM	0.997	
				SGD	0.98	
15	Enhancing Precision in Tulsi Leaf Infection Classification: A Stacking Classifier Ensemble Strategy	Kaur, M.	2024	SVM,RF	97.65	[2]
				SVM,RF	98.25	
				SVM,RF,DT	95.38	
				SVM,RF,DT,MLP	97.35	

The table II includes several studies on plant leaf and disease classification utilizing deep learning and machine learning techniques. These studies encompass a range of plants and diseases, employing various algorithms and models. Overall, the table demonstrates the varying accuracies of the models based on the specific study and approach used. This analysis underscores the effectiveness of deep learning and machine learning in plant disease classification, indicating a promising direction for future research in this field.

V. FUTURE SCOPE/CONCLUSION

Our study focused on automating the identification of medicinal plants, particularly those used for medicine in regions with diverse plant species. We discovered that analysing the leaves of different types of Tulsi plants can help us determine which ones are used for medicine, thereby improving the efficiency of medicine production. In the future, we aim to enhance our method by exploring more advanced computer techniques and utilizing larger datasets. Collaboration with farming experts will also be crucial to ensure the practicality and effectiveness of our approach in real-world settings. Automating the identification of medicinal plants is essential as manual identification is time-consuming and prone to errors. We utilize sophisticated computer programs to analyse leaf patterns and expedite the identification process. However, further research is needed, especially regarding images taken in varying lighting conditions and backgrounds. The availability of a substantial dataset is also critical for refining our method. The primary challenge we face is the lack of sufficient data for Tulsi plants. Improving our plant identification and disease classification system not only benefits medicine production but also contributes to environmental conservation.

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