

Allelopathic medicinal plants identification using computer vision in Marunthuvazh Malai, Kanyakumari, India

T. Sahila* and A. Radhakrishnan

Department of Information Technology, University College of Engineering
Nagercoil-629004, Kanyakumari District, India.

E.mail : statsahila@gmail.com, arkrish77annauniv@gmail.com

(Received in revised form: September 13, 2024)

CONTENTS

- 1. INTRODUCTION**
- 2. MEDICINAL PLANTS STUDUED**
- 3. COMPUTER IMAGING**
- 4. TECHNIQUES USED**
- 5. DATASET DESCRIPTION**
- 6. PROPOSED METHODOLOGY**
- 7. RESULT AND DISCUSSION**
- 8. CONCLUSIONS**
- 9. REFERENCES**

ABSTRACT

Medicinal plants contain medicinal properties in their all-plant parts. There is human vision error for medicinal leaves with lookalike leaves, hence, computer vision is required. We examined the 9-medicinal plants leaves native to the Marunthuvazh malai hills (Kanyakumari district) Western Ghats. for their medicinal value using image processing. For this we look two datasets, (i).dataset (1215 images) and (ii).Validation dataset (655 images). Various machine learning techniques used here produced very encouraging findings of this algorithm for use in medicinal plants system. A random forest algorithm, which is an ensemble feature extraction approach based on color, texture, and geometrical elements, was utilized in the research to develop a method for determining the correct species of medicinal plant. The proposed convolution neural network achieved a high-test accuracy 0.9975, precision 1.0, recall 0.9948 and F1score is 0.9974. In future, this study could be expanded to include large number of plant species with high level of precision.

Keywords: Allelopathy medicinal plants, computer vision, Convolutional Neural Network, Leaf Image Pre-processing plants, Particle Swarm Optimization (PSO), Random Forest

1. INTRODUCTION

Allelopathic medicinal Plants are used to cure human illnesses or ailments (41,61). Their parts from the roots to the leaves are effective for medicinal use. Lemon balm (*Melissa officinalis*), Peppermint (*Mentha balsamea*), Bael (*Aegle marmelos*), Tulsi (*Ocimum sanctum*), Catnip (*Nepeta cataria*) and Stevia (*Stevia rebaudiana*) are six types of medicinal

*Correspondence author



Trachyspermum ammi
(Sprague)



Cissus quadrangularis (L.)



Dodonaea viscosa (Miller)



Pergularia daemia



Cycas circinalis (L.)



Aegle marmelos (L.)



Selaginella bryopteris

Figure 1. Medicinal plants leaves

plant leaves used in modern medicine (72). Certain leaves are used to treat common colds, skin irritation, blood impurities and digestive problem (32). Various techniques exist to recognize leaves based on their colour (12), size (53), texture (31) and form (7,28,49) e.g. Figure 1(12). Many people prefer chemical medications from plants because they are more convenient. Table 1 lists the medicinal plant leaves used for various medicinal purposes (14,18,70). There is a need to identify medicinal plants and their distribution. To recognize the images of the leaves, image processing methods are used (21,37,39,58,59). It is difficult to recognize medicinal plants, these are located in dense woods and their leaves are almost identical to one another. Classifying plant leaf diseases, segmenting individual leaves, and rating their quality have attracted the attention of scientists.

Table 1. Uses and descriptions of a variety of useful medicinal herbs

Name	Bot. name	Family	Part used	Medicinal uses	Ref.
Malabar nut	<i>Adhatoda vasica</i>	Acanthaceae	Flower, leaf, root	Tuberculosis, cough, breathing difficulties, and chronic asthma.	14
Aegle marmelos	<i>Aegle marmelos</i> L.	Rutaceae	Leaves, roots, fruits	Antiviral, diuretic, antifertility, anticancer.	14
Aristolochiabr acteolata	<i>Aristolochia bracteata</i>	Aristolochiaceae	Whole plant	Antidote for snake venom, stomach aches, and bloody stools.	14
Giant Hogweed	<i>Aristolochia indica</i>	Aristolochiaceae	Leaves, root	Leprosy, anaemia, lipidaemia, snakebite, and scorpion stings.	15
Gigantic swallow wort	<i>Calotropis gigantea</i>	Asclepiadaceae	Leaves	Leprosy, anemia, snakebites, and spider stings.	15
Hyacinth Bean	<i>Cassia auriculata</i>	Caesalpiniaceae	Flower, leaf, root, fruit, resin, barks	Dry skin, bad body odor, dizziness, skin brightening.	14
Lemon	<i>Citrus medica</i>	Rutaceae	Leaf, juice	Digestive issues, earache, excessive hair growth, and brittle nails.	16
Bermuda grass	<i>Cynodon dactylon</i>	Poaceae	Whole plant	Urinary problems, piles, skin conditions, Eye problems,	14
Thorn Apple	<i>Datura metel</i>	Solanaceae	Leaves, flowers, seed	Acidity, breast engorgement, earache, wound healing, skin infections and asthma.	14
Dodonaea viscosa	<i>Dodonaea viscosa</i> (Miller)	Soapberry	Root, leaves	Laxative, apasmolytic, antiviral, anti-inflammatory.	16
Snake weed	<i>Euphorbia hirta</i>	Euphorbiaceae	Flower, leaf	Asthma, skin ailments, dengue fever and malaria.	15
Indigo	<i>Indigofera Tinctoria</i>	Fabaceae	Leaf, root	Cure snake and spider venom, bites, jaundice and menstrual issues.	16
Drumstick Tree	<i>Marsilea quadrifolia</i>	Marsileaceae	Leaf	Lowering body temperature, haematuria, produce milk.	15
Curry	<i>Oldenlandia umbellata</i>	Rubiaceae	Leaves, root	Coughing fits, itchy legs, and a cold/flu-like illness.	14
Pergularia	<i>Pergularia daemia</i>	Apocynaceae	Flowering	Malarial intermittent fevers	15
Selaginella stellata	<i>Selaginella</i>	Selaginellaceae	Food	Fever, epilepsy, leucorrhoea, beri-beri, and cancer.	16

Sida acuta	<i>Sida caprinifolia</i>	Malvaceae	Leaf	Arrest bleeding.	15
Carom seeds	<i>Trachyspermum ammi</i>	Apiaceae	Leaves	Treating spasmodic pains, and heartburn.	14
Indian Ginseng	<i>Withania somnifera</i>	Solanaceae	Whole plant	Pneumonia, bed sores, and pluresy.	14
Indian jujube leaf	<i>Ziziphus jujube</i>	Rhamnaceae	Leaves, bark, root	Appetite increase, blood in the stools, and uterine issues.	14

It is important to collect information of the medicinal characteristics of these plants' leaves. The physical inspection of leaves is labour-intensive and calls for an automated system to rapidly evaluate the leaves and assess their therapeutic characteristics. To tackle these issues, we used the leaves image pre-processing techniques to identify the leaves of medicinal plants. The Marunthuvalzh Malai (Home of medicinal plants") of Kanyakumari District, Western Ghats, India covered with a variety of life-saving medicinal plants. The people in this village use these plants to treat snake and spider bites (26,66). This study aimed to (i). Collect a diverse dataset of leaf images of various allelopathic medicinal plant species with medicinal properties, (ii). Develop image pre-processing techniques to enhance the quality and clarity of leaf images, including noise reduction, contrast adjustment, and image normalization and (iii). Apply feature extraction algorithms to obtain texture, shape, and colour from the pre-processed leaf images.

1.1. Medicinal plants in Marunthuvalzh Malai (Kanyakumari District)

It is covered with a variety of life-saving medicinal plants used in medicine (2). About 60 % plants have therapeutic use, and about 80 are used in traditional medicine (40). Figure 2 indicates the Medicinal plant in Marunthuvalzh Hill (Kanyakumari district).





Figure 2. Medicinal plants in Marunthuvalzh Malai (Kanyakumari district)

2. MEDICINAL PLANTS STUDIED

2.1. *Aegle marmelos* (Rutaceae family, **Indian bael fruit**): It is a deciduous tree native to India (18 m height, stout trunk and rough, peeling bark) (Fig.3).



Figure 3. *Aegle marmelos* L.

The leaves are trifoliate, alternately arranged, with each leaflet being ovate to lanceolate with a pointed tip. The flowers are greenish-white, fragrant, borne in clusters. The fruit is globose, with a hard, woody shell and a sweet, aromatic pulp containing numerous seeds. The plant is used in traditional medicine for its therapeutic properties. It has various pharmacological properties (22). The plant's fruit is used in folk medicine, contains numerous phytochemicals such as marmeline, agelin, and flavonoids. Its fruits, leaves, and stems, possess antioxidant, antimicrobial, hypoglycemic, anti-inflammatory, analgesic, nephroprotective, and hepatoprotective effects (25). Extracts from its bark, leaves, or roots are used as laxatives, febrifuges, and expectorants, benefiting conditions like ophthalmia, deafness, inflammations, catarrh, diabetes, and asthma. Its fruits treat diarrhea, dysentery, stomachache, and cardiac ailments (3,14). It has antimicrobial, hypoglycemic, antidiarrheal, anti-inflammatory, wound healing, and gastroprotective effects. Bael also shows antineoplastic, radioprotective, chemoprotective, and chemopreventive properties, making it useful in cancer treatment and prevention. Its extracts reduce blood glucose, hydroperoxides, ceruloplasmin, and α -tocopherol levels in rats. It also increased plasma reduced glutathione and Vitamin C levels and the extract's has hypoglycemic activity (36).

2.2. *Cycas circinalis* (Queen sago): It is a slow-growing, perennial gymnosperm with stout, cylindrical trunk covered with leaf bases and scales. The leaves are pinnate, dark green and arranged in a rosette at the top of the trunk, with individual leaflets being linear to lanceolate. The plant is dioecious, with male plants producing large, cylindrical cones and female plants bearing ovulate cones. The seeds are large, fleshy, and typically red to orange. This species is often used ornamentally and has traditional medicinal uses (42). We studied the antibacterial activity of *Cycas circinalis* L. (Queen Sago) against *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, and *Xanthomonas axonopodis* (16). The ovule, comprising sarcotesta, sclerotesta, and endotesta layers, was extracted with various solvents. The methanol extract of the endotesta showed significant antibacterial activity, with inhibition zones of 14-18 mm, outperforming Vancomycin, Penicillin, and Bacterimycin. Phytochemical analysis identified alkaloids, saponins, and carbohydrates in the active extract. Figure 4 depicts the *Cycas circinalis* in Population and in Single plant respectively.



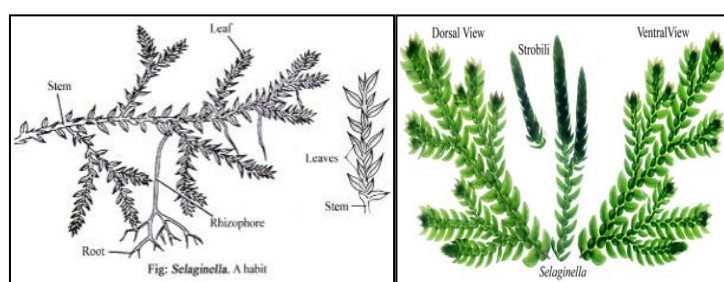
Figure 4. *Cycas circinalis*

2.3. *Pergularia daemia*: It is a twining vine found in tropical regions. It features opposite, heart-shaped leaves with a prominent midrib and a rough texture. Figure 5 depicts the *Pergularia daemia* in Population and in Single plant respectively. The stems are slender and pubescent, twining around support structures. Flowers are small, greenish-yellow and arranged in umbellate clusters. The fruit is a pair of follicular pods, containing numerous seeds with tufts of silky hairs for wind dispersal. This plant is noted for its medicinal properties in traditional remedies for various ailments. We analyzed the phytochemical properties and antioxidant capacity of *Pergularia daemia*, a medicinal plant (25). Using n-hexane, ethyl acetate, and ethanol extracts from leaves and stems, they found flavonoids, steroids, terpenoids, and glycosides. The ethanol extract showed the highest concentrations of flavonoids and phenolic compounds. The study confirmed the plant's traditional medicinal uses. Its anti-arthritic potential was studied using methanolic extracts on rats (6). Phytoconstituents identified by LC-ESI/MS included flavonoids like formononetin and quercetin. Histological analysis showed reduced joint damage and inflammation. Its anti-arthritic effects were due to its bioactive flavonoids, supporting its traditional use for treating arthritis. We studied its hepatoprotective effects on rats with liver damage(67). The ethanolic extract (200 mg/kg) significantly reduced liver enzyme levels and improved protein and albumin levels, similar to silymarin. Histopathology supported these results, and flavonoids were suggested as active compounds. The study concluded that its ethanolic extract has significant hepatoprotective properties.

Figure 5. *Pergularia daemia*

2.4. *Selaginella stellata* (spike moss). It is a genus of primitive vascular plants, have small, scale-like leaves with a creeping or climbing growth habit. Figure 6 depicts the *Selaginella* in Population and in Single plant respectively (57). The stems are dichotomously branched, forming a dense mat or cushion.

Selaginella species produces sporangia on specialized leaves called sporophylls, clustered in strobili at the tips of branches. They exhibit heterospory, producing both microspores and megaspores. They thrive in moist, shaded environments. The *Selaginella* species are used globally for ailments like fever, jaundice, and cardiac diseases (1,17). Flavonoids were the most active components. Crude extracts showed antimicrobial, antiviral, anti-diabetic, anti-inflammatory, anticancer, and anti-Alzheimer effects. We studied (30) *Selaginella tamariscina*, traditionally used in Oriental medicine for cancer, hepatitis, and diabetes. The plant contains bioactive compounds like selaginellins, known for their anticancer, antidiabetic, and neuroprotective activities. The study investigated the drug interaction potential of two selaginellins on various cytochrome P450 (P450) and UGT isoforms using human liver microsomes. Selaginellin and selaginellin M showed high inhibitory potential for CYP2C8 and moderate for CYP2C9, CYP2J2, UGT1A1, and UGT1A3. This data helps to predict drug interactions with selaginellins. The anti-inflammatory effects of *Selaginella bryopteris*, used traditionally in Indian medicine were investigated (48). They tested aqueous, polar, and non-polar methanolic extracts on TPA-induced inflammation in mice. The non-polar methanolic fraction (10 mg/20 μ L) significantly reduced redness, edema, lipid peroxide, nitric oxide, and pro-inflammatory cytokines (TNF- α , IL-1 β , IL-6), similar to the control indomethacin. No toxicity was

Figure 6. *Selaginella stellata*

observed at doses up to 2000 mg/kg. The study concluded that *S. bryopteris* has significant anti-inflammatory properties, supporting its traditional use for treating inflammatory conditions. We studied the medicinal properties of *Selaginella bryopteris*, known for its resurrection capabilities. The aqueous extract of *S. bryopteris* enhanced cell growth by 41% in Sf9 cells and 78 % in mammalian cells (63). It protected cells from oxidative and UV-induced damage and provided complete protection against heat-induced growth suppression. The anti-stress and antioxidant effects are due to its hexose and protein content for its therapeutic potential (34).

2.5. *Dodonaea viscosa* (Hopbush): It is an evergreen small tree (5 m tall). It has smooth, greyish bark and simple, lanceolate leaves. Figure 7 depicts the *Dodonaea viscosa* in Population and in Single plant respectively. The flowers are small, yellow-green, and lack petals, arranged in terminal clusters. The fruit is 3-winged capsule that turns red-brown at maturity. This species is highly adaptable to variety of soil types and climates and used in traditional medicine. We studied the protective effects of *Dodonaea viscosa* extracts (methanol and chloroform) against CCL4-induced toxicity in mice (69). The methanol extract (DVM) showed superior protective effects on liver, kidney, and spleen, restoring enzyme and hematological levels, and improving antioxidant enzyme activity. Phytochemical analysis identified flavonoids, phenolics, gallic acid, epicatechin, and cumeric acid. The DVM extract also exhibited anti-tuberculosis activity. The study concluded that *D. viscosa* has significant therapeutic potential due to its antioxidant compounds. Khan et al. (37) studied the reproductive toxicity of *Dodonaea viscosa* using zebrafish embryos. Methanolic crude extract and hexane fraction showed higher toxicity than chloroform and butanol fractions. GC-MS identified phytol and methyl ester of hexadecanoic acid as major compounds. The study concluded that *D. viscosa* poses reproductive toxicity risks and requires careful use and dosage monitoring in pregnant patients. Dermatotoxicity of *Dodonaea viscosa* used in Ethiopia for skin diseases was evaluated (68). Skin irritation in rabbits was negligible (index 0.45). Sensitization in mice showed no response at 12-30 mg/mL. Acute and repeated dermal toxicity in rats showed no toxicity. These results suggest *D. viscosa* is safe for dermal use, supporting its potential for clinical trials.



Figure 7. *Dodonaea viscosa* Miller

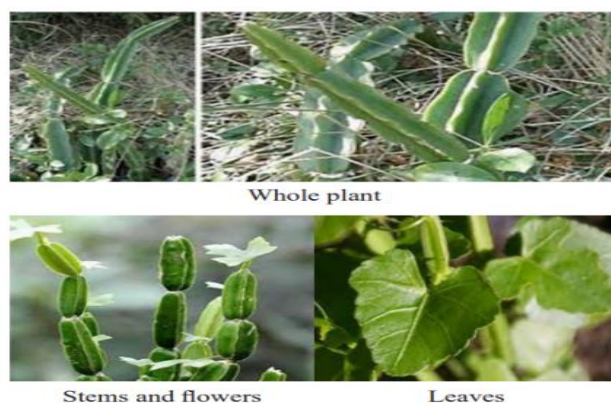
2.6. *Trachyspermum ammi* (Apiaceae family, Ajwain): It is an annual herbaceous plant grows up to 90 cm tall, with feathery, pinnate leaves and small, white flowers arranged in compound umbels. Figure 8 depicts the *Trachyspermum ammi* in Population and in Single plant respectively. The seeds are small, oval, and ridged, with a strong, aromatic thyme-like scent. Its seeds are used as a spice due to their medicinal properties, particularly in digestive

health (9, 75). We identified the primary structure of a 9.66 kDa non-specific lipid transfer protein 1 (nsLTP1) from ajwain seeds (45). The nsLTP1, purified via chromatography, has 91 amino acids and eight conserved cysteines. Its 3D structure features four α -helices stabilized by disulfide bonds. Structural validation used tools like ERRAT and PROCHECK. Docking and MD simulations with myristic and oleic acids highlighted key lipid-binding residues: Leu11, Leu12, Ala55, Ala56, Val15, Tyr59, and Leu62. Javed *et al.* (35) studied *Trachyspermum ammi*, finding positive phytochemical tests for flavonoids, tannins, and steroids, and high nutritional value. The methanolic extract showed the highest antifungal and antibacterial activity. The n-hexane extract had the strongest antibacterial effect, with inhibition zones up to 4.76 cm against various bacteria. The study concluded that *T. ammi* extracts, especially n-hexane and essential oil, possess significant antimicrobial properties.

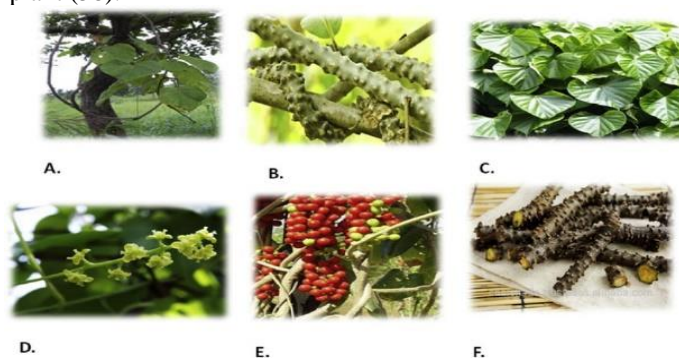


Figure 8. *Trachyspermum ammi* L.

2.7. *Cissus quadrangularis*: It is a perennial vine with quadrangular, jointed stems. The stems are succulent and green, with tendrils for climbing. The leaves are simple, ovate, and toothed, with a glossy surface. Figure 9 depicts the *Cissus quadrangularis* in Population and in Single plant respectively. Small, greenish-white flowers are borne in cymes, followed by globular, reddish-black berries. This plant is widely used in traditional medicine for bone health and other ailments. The *Cissus* alleviated bone pain and in combination products, significantly reduced body weight, LDL, triglycerides, total cholesterol, and fasting blood sugar compared to placebo. No serious adverse effects were reported. The evidence quality varied from low (bone fractures) to high (hemorrhoids, weight reduction). *Cissus* was beneficial for bone fractures and effective for obesity/overweight, but more high-quality studies are needed. We studied the medicinal properties of *Cissus quadrangularis* for treating hemorrhoids (47). The methanol extract showed significant analgesic effects by reducing writhes and licking time in mice. It also inhibited edema formation in rats, indicating anti-inflammatory properties. Additionally, it had a venotonic effect on human umbilical veins. These results support the traditional use of *C. quadrangularis* for alleviating pain and inflammation and reducing hemorrhoid size.

Figure 9. *Cissus quadrangularis*

2.8. *Tinospora cordifolia*: It is a deciduous climbing shrub with long, slender, twining stems covered in a corky bark (58). The leaves are heart-shaped, with a prominent pointed tip and a smooth texture. Small, yellowish flowers are borne in axillary and terminal racemes. The fruit is a drupe, red when ripe. It is highly valued in Ayurveda for its immunomodulatory, antipyretic, and anti-inflammatory properties. The analgesic activity of Guduchi (*Tinospora cordifolia*) extract was evaluated on albino rats (27). The study concluded that Guduchi extract possesses analgesic activity, likely involving both peripheral and central mechanisms. Upadhyaya et al. (70) examined the immunomodulatory and cytotoxic properties of *Tinospora cordifolia* aqueous extract and concluded that *Tinospora cordifolia* has significant immunomodulatory potential. The Figure 10 depicts the *Tinospora cordifolia* in Population and in Single plant (58).

Figure 10. *Tinospora cordifolia*

3. COMPUTER IMAGING

Bose *et al.* (19) presented a plant disease-detecting device that operates automatically. High-resolution images of leaves are utilized for both the training and testing processes. Region-based and color-based region thresholding approaches are used to distinguish between healthy and diseased areas of a leaf. Histogram Oriented Gradient (HOG) and the Local Binary Pattern (LBP) techniques were used for feature selection. Finally, a Support Vector Machine (SVM) was employed for binary and multi-class classification. Feature

selection procedures are shown to be accurate using the SVM. The automated system is made more accessible by the development of a graphical user interface.

Azadnia *et al.* (13) developed to assess and categorize *Pelargonium sidoides*, *Origanum vulgare*, *Trigonella foenum-graecum*, *Falcaria vulgaris*, and *Rumex acetosa* as the most widely used medicinal herbs in Iran. The images of the plants were taken using a smartphone's camera. Multiple classes of the MP under study were classified using artificial neural networks, and the most effective classifier was chosen after being evaluated for error, correlation, and accuracy. The suggested method promises easy and accurate categorization of medicinal plants.

Naeem *et al.* (44) suggested a method for classifying the leaves of medicinal plants using machine learning. There are a total of 65 fused features retrieved from the dataset, which include spectral properties, run-length information, and texture. On an optimized medicinal plant leaves dataset, five machine learning classifiers namely bagging, random forest, multi-layer perceptron, simple logistic and logit-boost are organized, and the multi-layer perceptron classifier show moderately encouraging accuracy of 99.01 % when associated with the competition.

Quoc *et al.* (50) recommended Vietnamese medicinal plant image recognition using a Convolutional Neural Network (CNN)(4,15). Several frameworks, including Visual Geometry Group Network (VGG16), Resnet50, InceptionV3, DenseNet121, Xception, and Mobile-Net, are compared and contrasted. Xception achieved the greatest level of accuracy possible, which was 88.26 %.

Zi *et al.* (78) intended this study to rapidly and accurately determine whether or not an image of a leaf is a therapeutic plant. The quality of the leaves used in herbal medicine formulation is dependent on their validity. Similar-looking leaves are more likely to be grouped incorrectly. Similar-looking leaves are differentiated using image processing techniques that consider several leaf attributes.

Amuthalingeswaran *et al.* (5) constructed a model using Deep Neural Networks (DNN) to identify medicinal plants. To train the model, they made use of around 8,000 images that belonged to four distinct categories. In the end, the authors were able to get a satisfactory accuracy level of 85% while testing using images obtained from open field land locations.

Mookdarsanit *et al.* (42) developed a CNN-based algorithm to recognize "Thai herbs" from a single image. In order to educate the computer model about 11 common "Thai herbs," including Siamese Rough-bush, Cumin, Cha Muang, Sweet Basil, and Holy Basil among others. They utilized 2,700 images annotated with the plants' medical characteristics. Recalls greater than 0.75 and precisions greater than 0.80 were achieved with the use of a Fast Region-CNN (Fast R-CNN) and a VGG-Net in the feature extraction framework and model architecture.

Barbosa *et al.* (15) introduce Herb Software, a mobile app that helps users quickly identify which plants are safe to eat and which are not, to raise public awareness of the importance of herbs regardless of whether this information is already well known. Pattern recognition and data analysis make use of many plant properties and attributes. Plants are employed for pattern recognition and data analysis based on their properties and qualities. To classify leaves, we first undertake a segmentation procedure depend on the LAC (Localized Active Contour) model acquire a characteristic and then apply Regularized

Logistic Regression (RLR) to train a classifier. Experiments validate the effectiveness of the method.

Sladojevic *et al.*, (64) emphasize the usage of deep convolutional networks to classify images of plant leaves to create a disease recognition model. The deep convolutional neural network training was executed through the utilization of a framework for deep learning that was developed by the group at Berkeley Vision and Learning Centre. According to the constructed model's trial findings, its accuracy ranged from 91 % to 98 % on individual class assessments, with an average of 96.3 %.

4. TECHNIQUES USED

4.1. Particle Swarm Optimization (PSO) (71).

It has two key component techniques (i) Artificial life and (ii) Swarm theory, which is inspired by the behavior of flocks of birds and fish. It has following benefits (51): (i). A PSO algorithm can store relevant information about environmental factors, (ii) It has an innate capacity to adapt to changing conditions. Optimum points can be found and followed with PSO in both static and dynamic settings. PSO is efficient in dealing with nonlinear, non-differentiable, multimodal issues (76). Optimizing non-linear functions in continuous form can be done via PSO. Compared to other optimization techniques, PSO's basic mathematical operation and small number of parameters make it CPU-efficient and cost-effective. There is no overlapping in PSO, however, there are following limitation of PSO algorithms: (i).The approach is imperfect due to its underlying partial optimism, which makes it difficult to precisely control its velocity and direction, (ii). It is not possible to solve scattering and optimization issues and (iii) The method does not address problems not related to the coordinate system (finding a solution to the energy field or determining the rules that govern how particles travel within the energy field).

A ring topology is used to depict the optimal position in the immediate area, whereas a comprehensive mesh topology signifies the global optimal location. Every particle has a position and a velocity. The following characteristics apply to the i^{th} particle: The particle positions are represented by x_i^k . velocities vector is denoted by v_i^k , $pBest_i$ denotes the current best position and $gBest_i$ denotes the global positions. The acceleration coefficients are denoted by c_1 and c_2 , while r_1 and r_2 are two random vectors whose values range from 0 to 1. The following formula describes the setup procedure.

$$x_i^0 = x_{min} + rand(x_{max} - x_{min}) \quad (I)$$

$$v_i^0 = \frac{x_{min} + rand(x_{max} - x_{min})}{\Delta t} \quad (II)$$

Particles start at a position of x_i^0 and accelerate to the best possible location. It is necessary to update all particles at time $k + 1$ with their new particle goal or fitness value for the following iteration. The following equations define PSO:

$$v_i^{k+1} = \omega v_i^k + c_1 rand_1 \times (pbest_i - x_i^k) + c_2 rand_2 \times (gbest_i - x_i^k) \quad (III)$$

$$cx_i^{k+1} = x_i^k + v_i^{k+1} \Delta t \quad (IV)$$

Where, v_i^k : Velocity of the i^{th} particle at the k^{th} iteration, ω : Inertia factor, The acceleration constants, c_1 and c_2 , are cognitive and social, respectively; the random numbers, $rand_1$ and $rand_2$, are between 0 and 1; for $i : 1, 2$; The i^{th} particle's current location at

the k^{th} iteration is denoted by x_i^k : $pbest_i$ Particle's best position $Best$:Particle's position, or global position. To attain optimal performance, we established the inertia weight as under (46).

$$\omega = \omega_{end} + (\omega_{start} - \omega_{end})e^{-\frac{ya}{y_{max}}} \tag{V}$$

Where, ω_{start} and ω_{end} are the starting and ending inertia values. y and y_{max} represent the current and maximum iteration number.

4.2. Convolutional Neural Network (CNN)

It is a procedure of DL archetypal for managing data with a grid design, such as photographs, which is stimulated by the construction of animal graphic pallium and intended to study spatial ladders of geographies mechanically and adaptively, from low- to high-level patterns. It is made up of 3-layers (or building blocks): pooling, convolution and completely connected layers (73). The form of the artificial neural network, known as CNNs, needs a convolutional layer, but can also include pooling, nonlinear, and completely connected layers to produce a Deep CNN (36). Its key advantage in comparison to previous models lies in its inherent ability to autonomously identify and discern salient features. There are a wide number of applications for CNNs, such as computer vision, Face Recognition, audio processing, etc. Similar to a regular neural network, the design of CNNs was influenced by neurons found in the cerebral cortex of human beings and other animals. This is a more particular example of how CNN mimics the complex visual cortex in a cat's brain. The structure of the CNN is seen in Figure 11 (29).As seen in Figure 11, the crucial components of CNN's design could be classified into five categories. A comprehensive description of each component can be found in the sections that follow.

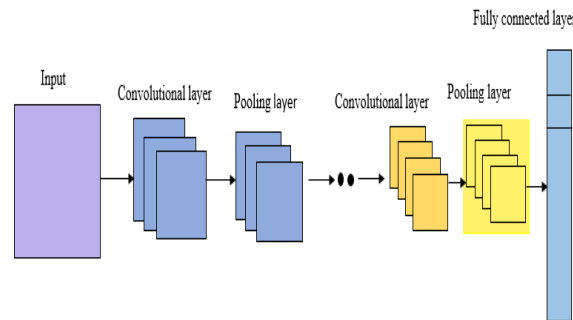


Figure 11. Structure of CNN

- (i). **Input layer:** The basic data set for the input layer could be directly sent into the input layer. The individual picture's pixel value is used to enter it into the input layer.
- (ii). **Convolutional layer:** There is a convolutional kernel that extracts distinct elements from the input data in each convolutional layer. Distinct convolutional kernels obtain different properties from the input data (Figure 11).
- (iii). **Fully connected layer:** The integrated properties of the convolutions preceding are used to generate a probability distribution for various circumstances within the layer.
- (iv). **Output layer:** The number of neurons present in a layer is determined by the specific parameters of the system.

5. DATASET DESCRIPTION

We used dataset of 9-medicinal plants viz., *Aegle marmelos* (Indian bael fruit), *Cycas circinalis*, *Pergularia daemia*, *Selaginella*, *Dodonaea viscosa*, *Cissus quadrangularis* and *Timnospora cordifolia* (Figure 12).



Aegle marmelos L.



Cycas circinalis



Pergularia daemia



Selaginella stellata



Aegle marmelos L.



Dodonaea viscosa Miller



Trachy spermumammi L.



Cissus quadrangularis



Timmospora timnospora

Figure 12. Categories of medicinal plants

In this research methodology, the author used 1215 images for training and 655 images for validation. In this study 141 images for training and 91 for validation purpose of *Aegle marmelos* (Indian bael fruit) class, 108 images for training and 48 for validation purpose of *Cycas circinalis* class, 183 images for training and 73 for validation purpose of *Pergularia daemia* class, 168 images for training and 98 for validation purpose of *Selaginella* class, 146 images for training and 96 for validation purpose of *Aegle marmelos* bael class, 74 images for training and 24 for validation purpose of *Dodonaea viscosa* class, 135 images for training and 85 for validation purpose of Ajwain class, 145 images for training and 85 for validation purpose of *Cissus quadrangularis* class, and 115 images for training and 55 for validation purpose of *Timmospora cordifolia* class. Table 2 describes the dataset images used in this study.

Table 2. Number of images contain by the train and validation dataset.

Plants	No. of images by train dataset	No. of images by validation dataset	Reference
<i>Aegle marmelos</i>	141	91	38
<i>Cycas circinalis</i>	108	48	62
<i>Pergularia daemia</i>	183	73	24
<i>Selaginella</i>	168	98	77
<i>Aegle marmelosbael</i>	146	96	14
<i>Dodonaea viscosa</i>	74	24	54
<i>Trachyspermum ammi L.</i>	135	85	20
<i>Cissus quadrangularis</i>	145	85	21
<i>Timmospora cordifolia</i>	115	55	59

6. PROPOSED METHODOLOGY

Authors collected the total data that needs to be sampled out into the input modulation process. After that it was splitted into two mechanisms (a) Based on validation, (b) Based on training. Based on the Cabelling process, the training parameters were only included in the data pre-processing condition with the inclusion of expert decision from the medicinal supervisor to extract the medical advantage of this processing input. After pre-processing the data, image pre-processing took place by removing basic iterations from the processing input like noise, cleansing, enhancement, etc. by applying two basic terminologies on the processing input source.

6.1. Grey Scale conversion: Changing an image’s format in digital photography can be done by this technique. It removes all colour information, leaving only gradations of grey, ranging from white to black.

6.2. Median filter: The filtering method known as median filter is applied to reduce noise from data, including pictures and signals. It preserves the edges, while reduces noise for the image processing industry. This is why it is so important. After analyzing both conditions, image segmentation took place to guide the basic parameter of the image in a segmented manner. After implementing all the parameters feature extraction terminology is applied to extract the guided principal parameters of the image such as shape, size, feature, runtime, etc. Feature extraction is done mainly by implementing the machine learning technology of Artificial Intelligence (AI) mechanism and the technique especially used is the PSO technique to optimize the current generalized image by converting it into non-theoretical condition by extracting the minima and maxima of that section of the image [4]. After that, the CNN concept is applied for furthermore extraction of features evolution mainly, the CNN technology analyzes the workflow features properly by applying three conditions mainly.

The proposed methodology of this study is described below in Figure 13, in which a dataset of 9 classes of image is split into training set and validation dataset.

6.2.1. Convolution: Convolution is a mathematical technique combining two signals to generate a third signal. The term “convolution” in digital signal processing, it shines out the most important term. When the tactic of impulse decomposition is used, it characterizes the impulse response, and this signal is called the impulse response signal.

6.2.2. Pooling: Pooling is included in the topologies of CNNs. The ‘accumulation’ of features from maps obtained by convolving a filter across an image is the primary objective of a pooling layer.

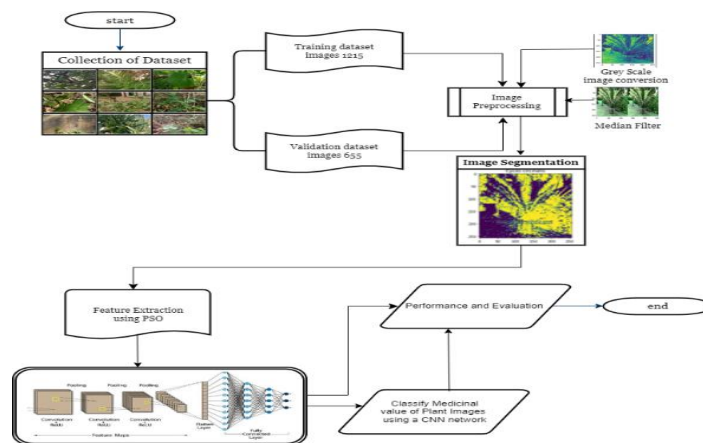


Figure 13. Proposed methodology

6.2.3. Flatten: It is practice using the latten layer in transition from the convolution layer to the fully connected layer. This layer is responsible for making the multidimensional input one-dimensional.

After all the evaluation check, the medicinal level of the image if it’s accessible pass it to the next modulation step, if unable to process then the process stops immediately. After that, classify medicinal values using convolutional neural network on a low, high, and Average range basis to analyze theology efficiently to extract the medicinal capacity perfectly of the selected training data module.

Then it is processed to convert RGB image into grey scale image and then the noise would be removed using digital median filter. This takes place at the beginning of the process. Afterwards the feature extraction is done by PSO technique. Then convolutional Neural network model is used to classify the medicinal plant or not and predict the output.

7. RESULTS AND DISCUSSION

7.1. Image pre-processing cleaning, noise removal, enhancement

There are many pre-processing methods applied to an image to improve it, filter it, smooth it out, or remove noise from it. The image would first be changed from its original RGB (red, green, and blue) form to a greyscale one, and then the noise would be removed using a median filter. This is done at the beginning of the process. The results are shown in Figure 14, which shows an image of each of the 9-medicinal plants classes alongside the original image, followed by converting the image into a greyscale format and the elimination of noise.

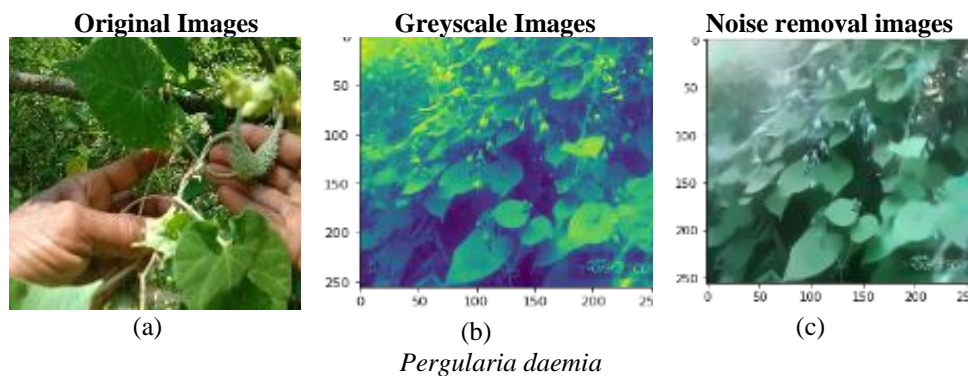


Figure 14. Pre-Processing Results. (a) Original RGB Image; (b) Grayscale Image (c) Noise removal.

7.2. Median Filter

The median filter is the first processing step in digital images to enhance the output of subsequent processing stages. It is utilized in this area, in specific circumstances, it can keep edges while eliminate noise. The result is presented in Figure15. In this figure, the author converts the original images of “*Pergularia daemia*” class into a greyscale image in the median filter.

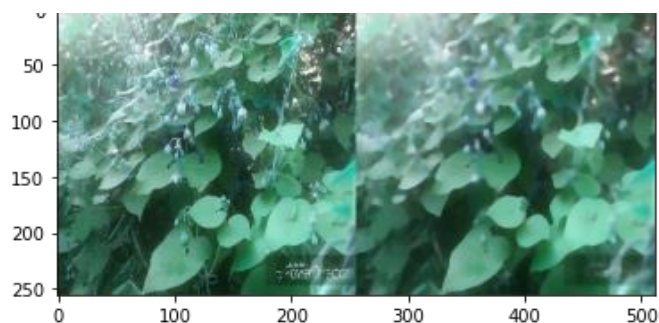


Figure 15. Median filter (a) Original image (b) Median filter of *Pergulariadaemia*.

7.3. Image Segmentation

In Figure 16, Pictures from the *Pergularia daemia* lesson were taken using an 8-megapixel phone. The threshold approach is the most straight forward technique for doing segmentation in image processing. It does this by analyzing the intensity of each pixel inside an image and comparing it to a predetermined value. It is helpful in situations in which the object of interest has a greater intensity than the backdrop (unnecessary parts). The segmentation process has been applied to the images taken by the camera.

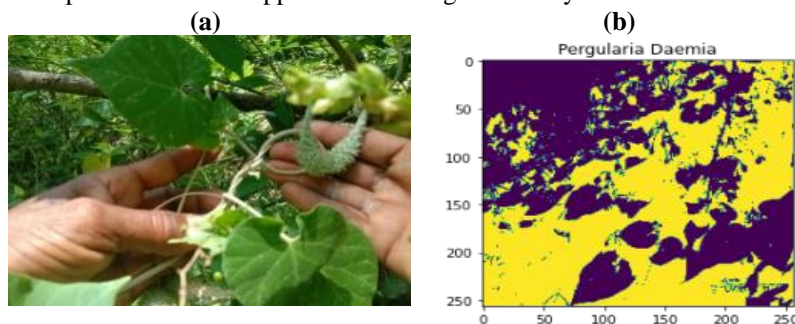


Figure 16. Segmentation Results of *Pergularia daemia* (a) Original RGB Image, (b) Image segmentation

7.4. Feature Extraction using PSO.

Author showed the various parameter used in the process of feature extraction using a Particle Swarm optimization (PSO) technique (Table 3).

Table 3. Show parameter of feature extraction used in PSO technique.

Hypermeter	Description	Possible values
Num particles	Number of particles in the swarm	Integer values (e.g., 10, 50, 100)
C1	Cognitive parameter (weight personal best)	Float values (e.g., 1.0, 1.5, 2.0)
C2	Social parameter (weight global best)	Float values (e.g., 1.0, 1.5, 2.0)
Max iterations	Maximum number of iterations	Integer values (e.g., 50, 100, 200)
Min bound	Minimum bound for particle positions	Float values (e.g., -5.0, -1.0, -0.5)
Max bound	Maximum bound for particle positions	Float values (e.g., 5.0, 1.0, 0.5)
Fitness threshold	Stopping criterion based on fitness value	Float values (e.g., 0.001, 0.0001, 0.00001)

7.5. Classification of medical leaf images using CNN network.

In CNN based classification of the medical images, we use various parameter (learning rate, number of epochs and batch size etc). Table 4 which showed these parameters of CNN model with their respective description and ranges. First, we used CNN to separate the red, green and blue components of the original image. The R-G-B segmentation findings on both the training and test datasets were positive. The Proposed CNN model has accuracy of 0.9975 to the classified medical leaf images from the image dataset. Fig 17(A) shows the accuracy of the proposed CNN model and Fig 17(B) illustrate the losses of the CNN model.

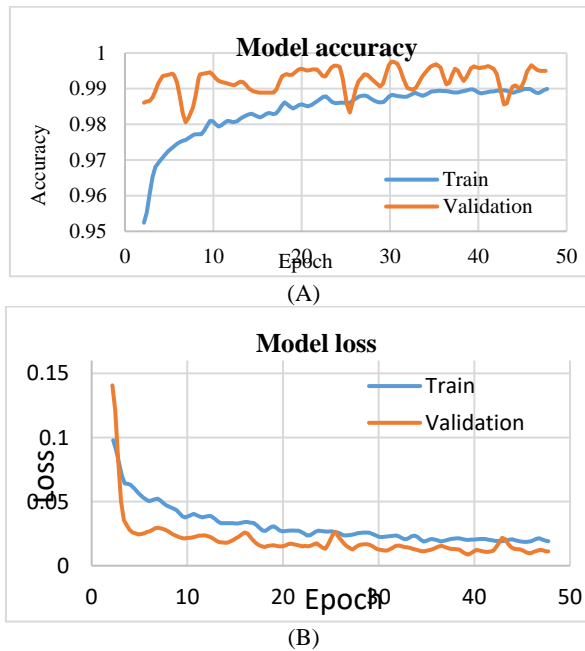


Figure 17. Accuracy and loss of proposed methodology. (A) shows the model accuracy of CNN network and (B) represents the losses of the model

Table 4. Hyperparameter of CNN based classification model.

Hyperparameter	Options/Range	Description
Learning Rate	[0.001, 0.01, 0.1]	The Rate at which the model adjusts based on the error.
Batch Size	[16, 32, 64]	Number of samples processed before the model updates.
Epochs	[10, 20, 30]	Number of times the model will iterate over the entire training dataset.
Optimizer	['adam', 'sgd']	It is Optimization algorithm used during training a model.
Loss Function	['categorical cross entropy', 'sparse categorical cross entropy']	The main objective of loss of function is that the model tries to minimize during training.
Dropout Rate	[0.3, 0.5, 0.7]	Fraction of input units dropped during training.
Convolutional Layers	[2, 3, 4]	Number of convolutional layers in the model.
Filter Size	[(3,3), (5,5)]	Size of the convolutional filters.
Pooling Size	[(2,2), (3,3)]	Size of the max pooling filters.

7.6. Classification of Medicinal Value of Medicinal Plants

In Table 5, we defined the medicinal value of 9-allelopathic medicinal plants viz., *Aegle marmelos* (Indian bael fruit), *Cycas circinalis*, *Pergularia daemia*, *Selaginella*, *Dodonaea viscosa*, *Trachyspermum ammi* (Ajwain), *Cissus quadrangularis* and *Timnospora cordifolia* using CNN network. Certain medicinal plants contain disinfection properties that kill disease-causing bacteria. They also prevent harmful microorganisms that spreads illnesses.

Table 5. Classification of the medicinal value of plants

Plant name	Medicinal value	Reference
<i>Aegle marmelos</i> (Indian bael fruit)	3	38
<i>Ajwain</i> (<i>Trachyspermum ammi</i>)	3	20
<i>Cissus quadrangularis</i>	4	21
<i>Cycas circinalis</i>	1	62
<i>Dodonaeaviscosa</i>	2	54
<i>Pergularia daemia</i>	1	24
<i>Selaginella stellata</i>	2	77
<i>Timnospora cordifolia</i>	4	59

CONCLUSIONS

Allelopathic medicinal plants are used to cure or prevent human illnesses or ailments. There are many herbal treatments which vary from place to place. The research devised a strategy to identify the proper species of medicinal plant by using a random forest algorithm, an ensemble feature extraction approach based on colour, texture, and geometrical aspects. The findings indicated that this algorithm is suitable for medicinal plants. It determines the outcome based on three parameters: accuracy, precision and recall. The proposed convolution neural network achieves a higher test accuracy 0.9975, precision 1.0, recall 0.9948 and F1score is 0.9974. In future, this study would be expanded to include more plant species while maintaining its high level of precision.

ACKNOWLEDGEMENTS

The author would like to express her sincere gratitude to his department for their invaluable contributions to this research paper. Their expertise and insights have been instrumental in shaping the direction of this study. The author extends our heartfelt thanks to all those who have contributed to the successful completion of this research.

8. REFERENCES

- Adnan, M., Siddiqui, A.J., Arshad, J., Hamadou, W.S., Awadelkareem, A.M., Sachidanandan, M. and Patel, M. (2021). Evidence-based medicinal potential and possible role of selaginella in the prevention of modern chronic diseases: Ethnopharmacological and ethnobotanical perspective. *Records of Natural Products* **15**(5): 355.
- Alamgeer, Sharif, A., Asif, H., Younis, W., Riaz, H., Bukhari, I.A. and Assiri, A.M. (2018). Indigenous medicinal plants of Pakistan used to treat skin diseases: A review. *Chinese Medicine* **13**: 1-26.

3. Alamri, Mubarak A. and Muhammad Tahir ul Qamar. (2023). Network pharmacology based virtual screening of Flavonoids from *Dodonea angustifolia* and the molecular mechanism against inflammation. *Saudi Pharmaceutical Journal* **31** (11): 1802.
4. Albawi, S., Mohammed, T.A. and Al-Zawi, S. (2017). Understanding of a Convolutional Neural Network. 2017 *International Conference on Engineering and Technology* (ICET). Antalya, Turkey. Pp.1-6.
5. Amuthalingeswaran, C., Sivakumar, M., Renuga, P., Alexpandi, S., Elamathi, J. and Hari, S.S. (2019). Identification of medicinal plants and their usage by using deep learning. In 2019 3rd *International Conference on Trends in Electronics and Informatics* (ICOEI) pp. 886-890. IEEE. 10.1109/ICOEI.2019.8862765
6. Ananth, D.A., Rameshkumar, A., Jeyadevi, R., Aseervatham, G.S.B., Sripriya, J., Bose, P.C. and Sivasudha, T. (2016). Amelioratory effect of flavonoids rich *Pergularia adaemia* extract against CFA induced arthritic rats. *Biomedicine and Pharmacotherapy* **80**: 244-252.
7. Ananthi, C., Periasamy, A. and Muruganand, S. (2014). Pattern recognition of medicinal leaves using image processing techniques. *Journal of Nanoscience and Nanotechnology* **2**(2): 214-218.
8. Anjum, V., Bagale, U., Kadi, A., Potoroko, I., Sonawane, S.H. and Anjum, A. (2023). Unveiling various facades of *Tinospora cordifolia* stem in food: Medicinal and nutraceutical aspects. *Molecules* **28**(20): 7073.
9. Anwar, S., Ahmed, N., Habibatni, S. and Abusamra, Y. (2016). Ajwain (*Trachyspermum ammi* L.) oils. In *Essential Oils in Food Preservation, Flavor and Safety*, pp. 181-192. Academic Press, New York.
10. Ariharan, V.N., Kalirajan, K., Devi, V.N. and Prasad, P. (2012). An exotic fruit which forms the new natural source for vitamin-C. *Rasayan Journal of Chemistry* **5**(3): 356.
11. Arshad, M., Chaudhary, A.R., Mumtaz, M.W., Raza, S.A., Ahmad, M., Mukhtar, H. and Bashir, R. (2021). Polyphenol fingerprinting and hypoglycemic attributes of optimized *Cycas circinalis* leaf extracts. *Journal of Science of Food and Agriculture* **101**(4): 1530-1537.
12. Arun, C.H., Emmanuel, W.S. and Durairaj, D.C. (2013). Texture feature extraction for identification of medicinal plants and comparison of different classifiers. *International Journal of Computer Applications* **62**(12): 1-9.10.5120/10129-4920.
13. Azadnia, R. and Kheiralipour, K. (2021). Recognition of leaves of different medicinal plant species using a robust image processing algorithm and artificial neural networks classifier. *Journal of Applied Research on Medicinal and Aromatic Plants* **25**: 100327.
14. Baliga, M.S., Thilakchand, K.R., Rai, M.P., Rao, S. and Venkatesh, P. (2013). *Aegle marmelos* (L.) Correa (Bael) and its phytochemicals in the treatment and prevention of cancer. *Integrative Cancer Therapies* **12**(3): 187-196.doi.org/10.1177/15347354124513.
15. Barbosa, J.B., Jabunan, V.I., Lacson, T.K., Mabayan, M.L. and Napone, G.M. (2017). HerbApp: A mobile-based application for herbal leaf recognition using image processing and regularized logistic regression classifier. *International Journal of Innovative Science and Research Technology* **2**(10).
16. Barroso, J.L.M., Lacanilao, D.C.G., Sac, R.A.C. and Vitor II, R.J.S. (2017). Antidiabetic effects of *Cycas riuminiana* leaf extracts on alloxan-induced diabetic ICR mice (*Mus musculus* L.). *National Journal of Physiology, Pharmacy and Pharmacology* **7**(12): 1390-1390.10.5455/njppp.2017.7.0831714092017.
17. Beshah, F., Hunde, Y., Getachew, M., Bachheti, R.K., Husen, A. and Bachheti, A. (2020). Ethnopharmacological, phytochemistry and other potential applications of *Dodonaea* genus: A comprehensive review. *Current Research in Biotechnology* **2**: 103-119.doi.org/10.1016/j.crbiot.2020.09.002
18. Bordoloi, C., Kumar, S., Barbhuiya, A.M., Kushari, S., Kalita, J.M., Sahu, B.P. and Laloo, D. (2023). Herbal medicine used for wound healing by the tribes of the North Eastern States of India: A Comprehensive Review. *Journal of Herbal Medicine* 100697.<https://doi.org/10.1016/j.hermed.2023.100697>
19. Bose, P., Dutta, S., Goyal, V. and Bandyopadhyay, S.K. (2021). Leaf diseases detection of medicinal plants based on support vector machine classification algorithm. *Journal of Pharmaceutical Research International* **33**(42A): 111-119. DOI: 10.9734/JPRI/2021/v33i42A32391.
20. Chatterjee, S., Goswami, N. and Bhatnagar, P. (2012). Estimation of phenolic components and *in-vitro* antioxidant activity of fennel (*Foeniculum vulgare*) and Ajwain (*Trachyspermum ammi*) seeds. *Adv Biores* **3**(2): 109-18. doi/full/10.5555/20123365395
21. Chidambara Murthy, K.N., Vanitha, A., Mahadeva Swamy, M. and Ravishankar, G.A. (2003). Antioxidant and antimicrobial activity of *Cissus quadrangularis* L. *Journal of Medicinal Food* **6**(2): 99-105.
22. Choudhary, Y., Saxena, A., Kumar, Y., Kumar, S. and Pratap, V. (2017). Phytochemistry, pharmacological and traditional uses of *Aegle marmelos*. *Pharmaceutical and Biosciences Journal* **5**(5): 27-33.
23. Dahigaonkar, T.D. and Kalyane, R. (2018). Identification of ayurvedic medicinal plants by image processing of leaf samples. *International Research Journal of Engineering and Technology* **5**(5): 351-355.
24. Doss, A. and Anand, S.P. (2012). Preliminary phytochemical screening of *Asteracantha longifolia* and *Pergulariadaemia*. *World Applied Sciences Journal* **18**(2): 233-235. 10.5829/idosi.wasj.2012.18.02.1136

25. Dosumu, O.O., Ajetumobi, O.O., Omole, O.A. and Onocha, P.A. (2019). Phytochemical composition and antioxidant and antimicrobial activities of *Pergularia daemia*. *Journal of Medicinal Plants for Economic Development* **3(1)**: 1-8. <https://journals.co.za/doi/abs/10.4102/jomped.v3i1.26>
26. Ekambaram, G. (2024). Indigenous medicinal plants of the Kani tribes in Kanyakumari District: Ethnobotanical documentation and quantitative study. *Indian Journal of Traditional Knowledge* **23(1)**: 39-48.
27. Goel, B., Pathak, N., Nim, D.K., Singh, S.K., Dixit, R.K. and Chaurasia, R. (2014). Clinical evaluation of analgesic activity of guduchi (*Tinospora cordifolia*) using animal model. *Journal of Clinical and Diagnostic Research* **8(8)**: HC01.10.7860/JCDR/2014/9207.4671
28. Gopal, A., Reddy, S.P. and Gayatri, V. (2012). Classification of selected medicinal plants leaf using image processing. In: 2012 *International Conference on Machine Vision and Image Processing (MVIP)* pp. 5-).
29. Gu, H., Wang, Y., Hong, S. and Gui, G. (2019). Blind channel identification aided generalized automatic modulation recognition based on deep learning. *IEEE Access* **7**: 110722-110729.
30. Heo, J.K., Nguyen, P.H., Kim, W.C., Phuc, N.M. and Liu, K.H. (2017). Inhibitory effects of selaginellins from *Selaginella tamariscina* (Beauv.) spring against cytochrome p450 and uridine 5'-diphosphoglucuronosyltransferase isoforms on human liver microsomes. *Molecules* **22(10)**: 1590.
31. Herdiyeni, Y., Lubis, D.I. and Douady, S. (2015). Leaf shape identification of medicinal leaves using curvilinear shape descriptor. In 7th *International Conference of Soft Computing and Pattern Recognition (SoCPaR)* (pp. 218-223). IEEE. 10.1109/SOCPAR.2015.7492810.
32. Ihsan, M.F., Sunyoto, A. and Arief, M.R. (2022). Gray level co-occurrence matrix algorithm and backpropagation neural networks for herbal plants identification. In *5th International Conference on Information and Communications Technology (ICOIACT)*, pp. 373-378.
33. Indolia, S., Goswami, A.K., Mishra, S.P. and Asopa, P. (2018). Conceptual understanding of convolutional neural network-a deep learning approach. *Procedia Computer Science* **132**: 679-688.
34. Isah, T. (2019). Stress and defense responses in plant secondary metabolites production. *Biological Research* **52**
35. Javed, S., Shahid, A.A., Haider, M.S., Umeera, A., Ahmad, R. and Mushtaq, S. (2012). Nutritional, phytochemical potential and pharmacological evaluation of *Nigella sativa* (Kalonji) and *Trachyspermum ammi* (Ajwain). *Journal of Medicinal Plants Research* **6(5)**: 768-775.10.5897/JMPR11.13410.
36. Kamalakkannan, N. and Prince, P.S.M. (2003). Hypoglycaemic effect of water extracts of *Aegle marmelos* fruits in streptozotocin diabetic rats. *Journal of Ethnopharmacology* **87(2-3)**: 207-210.
37. Khan, M.F., Alqahtani, A.S., Almarfadi, O.M., Ullah, R., Nasr, F.A., Noman, O.M. and Ahamad, S.R. (2021). The reproductive toxicity associated with *Dodonaea viscosa*, a folk medicinal plant in Saudi Arabia. *Evidence-Based Complementary and Alternative Medicine* **2021(1)**: 6689110
38. Kumar, S., Ram, R.B., Kumar, A., Kumar, R., Kumar, R. and Sharma, M.M. (2023). Physical attributes of Bael (*Aegle marmelos* L.) fruit and suitability for commercialization and processing. *International Journal of Plant & Soil Science* **35(15)** : 260-264.
39. Loddo, Andrea, Cecilia Di Ruberto, A.M.P.G. Vale, Mariano Uccesu, J.M. Soares and Gianluigi Bacchetta. (2023). An effective and friendly tool for seed image analysis. *The Visual Computer* **39 (1,2)**: 335-352.
40. Malik, M.N., Haq, I.U., Fatima, H., Ahmad, M., Naz, I., Mirza, B. and Kanwal, N. (2022). Bioprospecting *Dodonaea viscosa* Jacq, A traditional medicinal plant for antioxidant, cytotoxic, antidiabetic and antimicrobial potential. *Arabian Journal of Chemistry* **15(3)**: 103688.<https://doi.org/10.1016/j.arabjc.2022.103688>.
41. Mehta, P., Bisht, K. and Sekar, K.C. (2021). Diversity of threatened medicinal plants of Indian Himalayan Region. *Plant Biosystems* **155(6)**: 1121-113.
42. Mookdarsanit, L. and Mookdarsanit, P. (2019). Thai herb identification with medicinal properties using convolutional neural network. *Suan Sunandha Science and Technology Journal* **6(2)**: 34-40..
43. Mudannayake, A., Sooriyapathirana, S., Samaraweera, P. and Perera, A. (2015). Cycas Taxa in Sri Lanka and their morphological characteristics of taxonomic significance. *Ceylon Journal of Science (Biological Sciences)* **44(1)**.10.4038/cjsbs.v44i1.7337.
44. Naeem, S., Ali, A., Chesneau, C., Tahir, M.H., Jamal, F., Sherwani, R.A.K. and Ul Hassan, M. (2021). The classification of medicinal plant leaves based on multispectral and texture feature using machine learning approach. *Agronomy* **11(2)**: 263.<https://doi.org/10.3390/agronomy11020263>.
45. Nazeer, M., Waheed, H., Saeed, M., Ali, S.Y., Choudhary, M.I., Ul-Haq, Z. and Ahmed, A. (2019). Purification and characterization of a nonspecific lipid transfer protein 1 (nsLTP1) from *Ajwain* (*Trachyspermum ammi*) seeds. *Scientific Reports* **9(1)**: 4148. 10.1038/s41598-019-40574-x.
46. Nzanywayingoma, F. and Yang, Y. (2017). Analysis of particle swarm optimization and genetic algorithm based on task scheduling in cloud computing environment. *International Journal of Advance Computer Science Applications* **8(1)**: 19-25.

47. Panthong, A., Supraditaporn, W., Kanjanapothi, D., Taesotikul, T. and Reutrakul, V. (2007). Analgesic, anti-inflammatory and venotonic effects of *Cissus quadrangularis* L. *Journal of Ethnopharmacology* **110**(2): 264-270. [10.1016/j.jep.2006.09.018](https://doi.org/10.1016/j.jep.2006.09.018).
48. Paswan, S.K., Gautam, A., Verma, P., Rao, C.V., Sidhu, O.P., Singh, A.P. and Srivastava, S. (2017). The Indian magical herb 'Sanjeevni' (*Selaginella bryopteris* L.)-A promising anti-inflammatory phytomedicine for the treatment of patients with inflammatory skin diseases. *Journal of Pharmacopuncture* **20**(2): 93.
49. Putri, Y.A., Djamal, E.C. and Ilyas, R. (2021). Identification of medicinal plant leaves using convolutional neural network. *Journal of Physics: Conference Series* (Vol. 1845, No. 1, p. 012026). IOP Publishing. DOI [10.1088/1742-6596/1845/1/012026](https://doi.org/10.1088/1742-6596/1845/1/012026).
50. Quoc, T.N. and Hoang, V.T. (2020). Medicinal plants identification in the wild by using CNN. International Conference on *Information and Communication Technology Convergence (ICTC)*: 25-29.
51. Rostami, A. and Lashkari, M. (2014). Extended PSO algorithm for improvement problems K-Means clustering algorithm. *International Journal of Managing Information Technology* **6**(3): 17.
52. Sah, N.K., Singh, S.N.P., Sahdev, S., Banerji, S., Jha, V., Khan, Z. and Hasnain, S.E. (2005). Indian herb 'Sanjeevani' (*Selaginella bryopteris*) can promote growth and protect against heat shock and apoptotic activities of ultra violet and oxidative stress. *Journal of Biosciences* **30**: 499-505.
53. Salehi, B., Kumar, N.V.A., Şener, B., Sharifi-Rad, M., Kılıç, M., Mahady, G.B. and Sharifi-Rad, J. (2018). Medicinal plants used in the treatment of human immunodeficiency virus. *International Journal of Molecular Sciences* **19**(5): 1459.
54. Salinas-Sánchez, D.O., Herrera-Ruiz, M., Pérez, S., Jiménez-Ferrer, E. and Zamilpa, A. (2012). Anti-inflammatory activity of hauriwaic acid isolated from *Dodonaea viscosa* leaves. *Molecules* **17**(4) : 4292-4299.
55. Sathwik, T., Ysaswini, R., Venkatesh, R. and Gopal, A. (2013). Classification of selected medicinal plant leaves using texture analysis. In 2013 Fourth *International Conference on Computing, Communications and Networking Technologies (ICCCNT)* (pp. 1-6). IEEE. <https://doi.org/10.1109/ICCCNT.2013.6726793>.
56. Sawangjit, R., Puttarak, P., Saokaew, S. and Chaiyakunapruk, N. (2017). Efficacy and safety of *Cissus quadrangularis* L. in clinical use: A systematic review and meta-analysis of randomized controlled trials. *Phytotherapy Research* **31**(4): 555-567. <https://doi.org/10.1002/ptr.5783>.
57. Setyawan, A.D. (2011). Natural products from genus *Selaginella* (Selaginellaceae). *Nusantara Bioscience* **3**(1): 44-58.
58. Sharma, P., Dwivedee, B.P., Bisht, D., Dash, A.K. and Kumar, D. (2019). The chemical constituents and diverse pharmacological importance of *Tinospora cordifolia*. *Heliyon* **5**(9) 8. <https://doi.org/10.1016/j.heliyon.2019.e02437>
59. Sharma, U., Bala, M., Kumar, N., Singh, B., Munshi, R.K. and Bhalerao, S. (2012). Immunomodulatory active compounds from *Tinospora cordifolia*. *Journal of Ethnopharmacology* **141**(3): 918-926.
60. Shruthi, U., Nagaveni, V. and Raghavendra, B.K. (2019). A review on machine learning classification techniques for plant disease detection. In 2019 5th *International Conference on Advanced Computing and Communication Systems (ICACCS)*, pp. 281-284. IEEE. <https://doi.org/10.1109/ICACCS.2019.8728415>.
61. Simion, I.M., Casoni, D. and Sârbu, C. (2019). Classification of Romanian medicinal plant extracts according to the therapeutic effects using thin layer chromatography and robust chemometrics. *Journal of Pharmaceutical and Biomedical Analysis* **163**: 137-143. <https://doi.org/10.1016/j.jpba.2018.09.047>.
62. Singh, R. and Radha, P. (2008). A new species of Cycas (Cycadaceae) from Karnataka, India. *Botanical Journal of the Linnean Society* **158**(3) : 430-435. doi.org/10.1111/j.1095-8339.2008.00924.x
63. Singh, R., Sagar, N.A. and Kumar, N. (2022). Bio-inspired green fabrication of silver nanoparticles (AgNPs) using aqueous leaves extract of *Ipomoea carnea* Jacq. to tackle multiple drug resistance MTCC bacterial strains. *European Journal of Medicinal Chemistry Reports* **6**: 100066.
64. Sladojevic, S., Arsenovic, M., Anderla, A., Culibrk, D. and Stefanovic, D. (2016). Deep neural networks-based recognition of plant diseases by leaf image classification. *Computational Intelligence and Neuroscience* **2016**(1): 3289801.11 <https://doi.org/10.1155/2016/3289801>.
65. Sukumaran, S. and Raj, A.D.S. (2007). Rare, endemic, threatened (RET) trees and lianas in the sacred groves of Kanyakumari District. [doi/full/10.5555/20083021971](https://doi.org/10.5555/20083021971).
66. Sukumaran, S., Jeeva, S., Raj, A.D.S. and Laloo, R.C. (2007). Rediscovery of *Tectaria zeilanica* (Tectarioideae)-a rare fern from Vilavancode sacred grove, Southern Western Ghats, India.
67. Sureshkumar, S.V. and Mishra, S.H. (2006). Hepatoprotective effect of extracts from *Pergularia daemia* Forsk. *Journal of Ethnopharmacology* **107**(2): 164-168.
68. Teshome, K., Gebre-Mariam, T., Asres, K. and Engidawork, E. (2010). Toxicity studies on dermal application of plant extract of *Dodonaea viscosa* used in Ethiopian traditional medicine. *Phytotherapy Research* **24**(1): 60-69.

69. Tong, Z.W., Gul, H., Awais, M., Saddick, S., Khan, F. S., Gulfraz, M. and Khan, M. I. (2021). Determination of *in-vivo* biological activities of *Dodonaea viscosa* flowers against CCL4 toxicity in albino mice with bioactive compound detection. *Scientific Reports* **11**(1): 13336. <https://doi.org/10.1038/s41598-021-92638-6>.
70. Upadhyay, R.K. and Ahmad, S. (2012). Ethno-medicinal plants and their pharmaceutical potential. *Journal Pharma Research* **5**(4) : 2162-2173. <https://doi.org/10.1007/s00210-024-03034-6>.
71. Vijayashree, T. and Gopal, A. (2017, June). Leaf identification for the extraction of medicinal qualities using image processing algorithm. In 2017 *International Conference on Intelligent Computing and Control (I2C2)* pp. 1-4. IEEE. [10.1109/I2C2.2017.8321884](https://doi.org/10.1109/I2C2.2017.8321884)
72. Wang, D., Tan, D. and Liu, L. (2018). Particle swarm optimization algorithm: An overview. *Soft computing* **22**(2): 387-408. [10.1007/s00500-016-2474-6](https://doi.org/10.1007/s00500-016-2474-6)
73. Yamashita, R., Nishio, M., Do, R.K.G. and Togashi, K. (2018). Convolutional neural networks: An overview and application in radiology. *Insights into imaging* **9**: 611-629. [10.1007/s13244-018-0639-9](https://doi.org/10.1007/s13244-018-0639-9).
74. Yan, X., Bai, M., Ning, X., Ouyang, H., Zhang, S., Yang, M. and Wu, H. (2015). Spatiotemporal features of microsporogenesis in the cycad species *Macrozamia communis*. *American Journal of Botany* **102**(7): 1061-1072. <https://doi.org/10.3732/ajb.1500112>.
75. Zarshenas, M.M., Moein, M., Samani, S.M. and Petramfar, P. (2013). An overview on ajwain (*Trachyspermum ammi*) pharmacological effects; modern and traditional. *Journal of natural Remedies* **14**(1): 98-105. [doi/full/10.5555/20143177686](https://doi.org/10.5555/20143177686)
76. Zhan, S. and Huo, H. (2012). Improved PSO-based task scheduling algorithm in cloud computing. *Journal of Information and Computational Science* **9**(13): 3821-3829. [doi.org/121210277778%20\(2\)](https://doi.org/10.121210277778%20(2)).
77. Zhou, X.M. and Zhang, L.B. (2015). A classification of *Selaginella* (Selaginellaceae) based on molecular (chloroplast and nuclear), macromorphological, and spore features. *Taxon* **64**(6) : 1117-1140.
78. Zin, I.A.M., Ibrahim, Z., Isa, D., Aliman, S., Sabri, N. and Mangshor, N.N.A. (2020). Herbal plant recognition using deep convolutional neural network. *Bulletin of Electrical Engineering and Informatics* **9**(5): 2198-2205. doi.org/10.11591/eei.v9i5.2250.