AI-Driven Intelligent Agricultural Support System

Dr. Shweta Roy[1], AMIETE, MIEEE, **Dr. Kadambri Agarwal**[2], **D.K. Misra**[3] and **Dr. Sandhya Avasthi**[4], SMIEEE
Department of Computer Science Engineering, ABES Engineering College,
19th Kmstone, NH-9, Ghaziabad 201009 UP India
[1]shweta.roy@abes.ac.in, [2]kadambri.agarwal@abes.ac.in, [3]devendra.misra@abes.ac.in , [4]sandhya.avasthi@abes.ac.in

Abstract -- **Agriculture plays a critical role in supporting economies and lifestyles globally, but it continues to confront ongoing issues such as crop diseases, inefficient crop choices and incorrect fertilizer usage, all of which lead to decreased production and economic losses. In this research, we offer PhytoMate, an AI-powered intelligent agricultural support system meant to help farmers and agricultural experts make educated decisions to address these issues. PhytoMate uses powerful machine learning models, deep learning techniques and generative AI to provide a comprehensive solution that includes plant disease diagnosis, crop suggestion and fertilizer advice all on a single, user-friendly platform. The system uses a Convolutional Neural Network (CNN) trained on the publicly accessible Plant Village dataset to effectively detect and categorize plant illnesses based on supplied leaf photos. After successfully identifying the ailment, the system uses Google's Generative AI (Gemini API) to deliver thorough treatment suggestions, including preventative steps and corrective activities specific to the diagnosed condition.**

This module assesses the soil's nutrient composition and the crop's unique nutrient requirements in order to prescribe the best type and amount of fertilizer.

Keywords: *Machine learning, Deep learning, Generative AI, PhytoMate, Sreamlit, Plant disease detection, Crop recommendation, Fertilizer recommendation, Sustainable agriculture*

I. INTRODUCTION

AGRICULTURE is the foundation of many economies, particularly in underdeveloped nations where a large majority of the population depends on farming for a living. However, the agricultural industry continues to confront various ongoing issues, such as crop diseases, poor crop selection decisions, and inappropriate fertilizer use. These variables combine to reduce agricultural yields, cause financial losses, degrade soil, and eventually, jeopardize food security. In recent years, advances in artificial intelligence (AI) and machine learning (ML) have opened up new options for solving these concerns by providing data-driven solutions to help farmers make more educated decisions. One of agriculture's most common concerns is early diagnosis and treatment of plant diseases.

Traditional techniques of identifying plant diseases sometimes need specialist involvement, which may not be available to farmers in remote or rural regions. These procedures may also be time-consuming and prone to human error. Similarly, choosing the best crop for cultivation based on criteria such as soil quality, climate, and season is critical for optimizing production, but it is frequently led by intuition or broad suggestions rather than specific, data-driven insights. Furthermore, inappropriate fertilizer usage, whether excessive or insufficient, can impair soil fertility, cause nutrient imbalances, and have a detrimental long-term influence on crop output. Recognizing these crucial problems, we propose PhytoMate, an intelligent, AI-driven decision support system designed to provide farmers with easily accessible and accurate agricultural counsel.

Building on this basis, PhytoMate promises to bridge the gap between current technology and traditional agricultural techniques by providing farmers with real-time, actionable knowledge directly. Using deep learning models, the system can effectively diagnose plant illnesses from leaf photos, minimizing the need for expert consultations and enabling for faster actions. The crop recommendation module analyzes input factors such as soil type, pH level, moisture, and temperature to select the best crops for a certain location and season, maximizing land usage and boosting profitability.

PhytoMate combines three key features—plant disease identification via image analysis, crop suggestion based on environmental and soil conditions, and accurate fertilizer guidance—into a single, user-friendly platform. This comprehensive approach not only simplifies agricultural decision-making, but it also encourages sustainable farming practices and helps to increase total crop output and farm efficiency.

The method uses a deep learning-based Convolutional Neural Network (CNN) to accurately detect plant illnesses from leaf photos. To improve the usefulness of illness detection, PhytoMate uses Google's Generative AI (Gemini API) to deliver individualized therapy recommendations based on the discovered ailment. The system incorporates a wide range of machine learning algorithms, including logistic regression, XGBoost, support vector machines (SVM), decision trees, NaiveBayes, and convolutional neural networks (CNNs) with ReLU activation. Olfs *et al.* (2005) employ these methods together to properly categorize Nitrogen fertilizer recommendations for arable farming depending on soil and plant composition.

The Journal of Plant Nutrition and Soil PhytoMate includes a machine learning-based crop recommendation engine that examines soil nutrient levels (nitrogen, phosphorus, potassium), environmental characteristics (temperature, humidity, pH and rainfall), and recommends the best crops for a specific location. In addition, the fertilizer recommendation module assesses the soil composition and crop choice to recommend suitable fertilizer kinds and amounts, guaranteeing balanced nutrient application and supporting sustainable agricultural practices. The system is built with Streamlit, which provides an interactive and user-friendly online interface that enables farmers and agricultural experts to engage with the models and receive real-time advice. PhytoMate's goal is to bridge the gap between contemporary AI developments and practical agricultural applications by combining machine learning, deep learning and generative AI.

The system assists farmers in selecting the appropriate nutrient applications by analyzing soil type, crop requirements, and environmental conditions to give crop-specific fertilizer recommendations as well as disease detection. The tool enables accessibility by providing a web-based interface via which agricultural communities may readily access cutting-edge machine learning algorithms. This study illustrates how a platform that combines disease detection and recommendation may encourage data-driven, sustainable farming approaches, resulting in increased crop yields and disease resilience. This study describes the design, methodology and implementation of PhytoMate, assesses its effectiveness, and examines the possible influence on agricultural production and sustainability.

II. RELATEDWORK

The study by Bhambere [1] presents a CNN-based model for identifying plant illnesses and prescribing fertilizers. To boost agricultural productivity, it automates sickness categorization using image processing techniques such as segmentation and feature extraction. Compared to traditional expert-driven analysis, the technique is more successful and cost-efficient, while also offering timely, precise suggestions for sickness detection and prevention.

Orchi [2] explores recent breakthroughs in agricultural disease detection using the Internet of Things and artificial intelligence technologies. It investigates different deep learning, machine learning, and image processing algorithms, highlights issues. In contrast to traditional methodologies, the study emphasizes AI's promise for precise, scalable, and efficient disease diagnosis of pests and plant diseases, which increases research productivity and technology adoption.

Revathi *et al.* [3] propose a complete method for improved farming in dry environments that includes plant disease detection and crop suggestion. It generates tailored crop recommendations using soil/weather data and a LightGBM model. Furthermore, deep learning (ResNet50) enables early crop disease identification and prompt intervention. A simple user interface makes it easy to make efficient, data-driven judgments on best agricultural methods.

Evtimova-Gardair *et al.* presents a multi-agent recommendation, which employs AI and semantic technologies to offer exact plant disease and treatment recommendations. Using ontology and thesaurus integration to increase search precision, the system provides reliable, personalized disease information by combining plant characteristics with user-entered symptoms. It enables early, data-driven actions for improved crop health and yield, with 97% accuracy and 94% recall.

Isinkaye [5] emphasizes the need for improved detection approaches while examining advancements in the field of plant disease diagnosis. Disease identification and treatment are enhanced by merging deep learning with content-based filtering, which is critical for sustainable agriculture. To increase food security and agricultural production, the study underscores the promise of modern techniques for precise disease detection and control, while also emphasizing research requirements.

To address the challenges of visual disease assessment across large farms, Banothu *et al.* [6] offer a DenseNet-based deep learning (DL) model for early plant disease detection and pesticide recommendations. Plant pathologists confirmed the DenseNet model's accuracy of more than 92%, demonstrating its potential as a scalable cloud-based solution for accurate and user-friendly disease control. This approach enables rapid disease identification and treatment, which promotes sustainable agriculture.

Mohanty's study uses a deep convolutional neural network trained on a dataset of 54,306 pictures to examine smart phone-assisted crop disease detection [7]. The model is 99.35% accurate in recognizing 26 disease categories and 14 crop species. This system, which employs deep learning and smartphone technology, enables rapid and widespread disease diagnosis, with the potential to significantly enhance agricultural health and food security.

Saleem [8] examines deep learning for plant disease diagnosis, stressing its better accuracy when compared to traditional machine learning. The architectures discussed include AlexNet, GoogLeNet, VGG, ResNet and more complex models such as VGG-Inception and PlantdiseaseNet. To assess sickness hotspots, visualization methods such as heat maps and saliency maps are used. The research also discusses the usage of models like 3D-CNN and GANs in combination with Hype-rspectral Imaging (HSI) and deep learning for early sickness detection. Despite advancements, there are still difficulties to address, such as the need for real-world information, enhanced visualization, and models that can be changed to varied scenarios.

In contrast to typical manual procedures, the work by Li *et al.* [9] emphasizes the objectivity of DL in feature extraction. It stresses the ability of deep learning models to automatically recognize and extract relevant information from plant pictures, hence enhancing disease diagnosis and classification. The study also looks at recent improvements in DL models and shows how well they operate in agricultural contexts. Farmers gain from this study because it enables early disease detection, which reduces crop losses and enhances output.

III. METHODOLOGY

The PhytoMate system is intended to give total support to farmers by combining innovative technology for plant disease diagnosis, crop selection, and fertilizer optimization. The technique consists of numerous critical components, all of which contribute to the system's overall functioning.

System Architecture: Figure 1 depicts the general design of PhytoMate. The system consists of three main layers: the user interface, the backend processing modules and the output production components. The user interface enables farmers to enter data and obtain advice. The backendprocessing consists of modules for picture analysis, environmental data processing, and interaction with external APIs such as Gemini. The output components provide actionable information to the user.

Plant Disease Detection: A key aspect of PhytoMate is its capacity to identify plant diseases via picture processing. The process flow is depicted in Figure 2. Users provide photographs of plant leaves displaying symptoms. These photos are preprocessed, including scaling, noise reduction and normalization to assure consistency and improve analysis quality. The preprocessed photos are then sent into a Convolutional Neural Network (CNN) model trained to detect various plant illnesses. The model's predictions allow the system to reliably diagnose certain illnesses.

Data Preprocessing: Accurate data preparation is critical to the correctness of the CNN model. Initially, photos are gathered from a variety of sources to form a strong dataset. The images are then subjected to noise reduction algorithms to remove any extraneous information. Normalization guarantees that pixel values are properly scaled, while resizing standardizes image dimensions. This preprocessing pipeline improves the model's Capacity to learn important characteristics while training.

Machine Learning: PhytoMate recommends crops and optimizes fertilizers using ML models trained on large datasets of environmental and soil characteristics. The training procedure is depicted in Figure 4. Data collection include acquiring information on soil type, rainfall, temperature, humidity, and pH level. After preprocessing and feature selection, models like Decision Trees or Random Forests are trained to forecast the best crops and fertilizer requirements depending on the input data. Model assessment ensures that forecasts are accurate and consistent.

Integration with Google Generative AI (Gemini): To give treatment recommendations for recognized plant illnesses, PhytoMate works with Google's Generative AI, known as Gemini. The interaction process is shown in Figure 3. Once the CNN model has detected an illness, it generates a query and sends it to the Gemini API. The AI provides recommended therapy alternatives, which are then presented to the user. This integration uses powerful AI capabilities to provide up-to-date and effective treatment options.

User Interface	→	Backend System	→	Output
1. User uploads plant image 2. Inputs environmental data	→	1. Plant Disease Detection (CNN) 2. Crop Recommendation (ML Model) 3. Fertilizer Recommendation 4. Integration with Gemini API	→	1. Disease Diagnosis 2. Crop Suggestion 3. Fertilizer Suggestion 4. Treatment Recommendation

Figure 1. System architecture diagram.

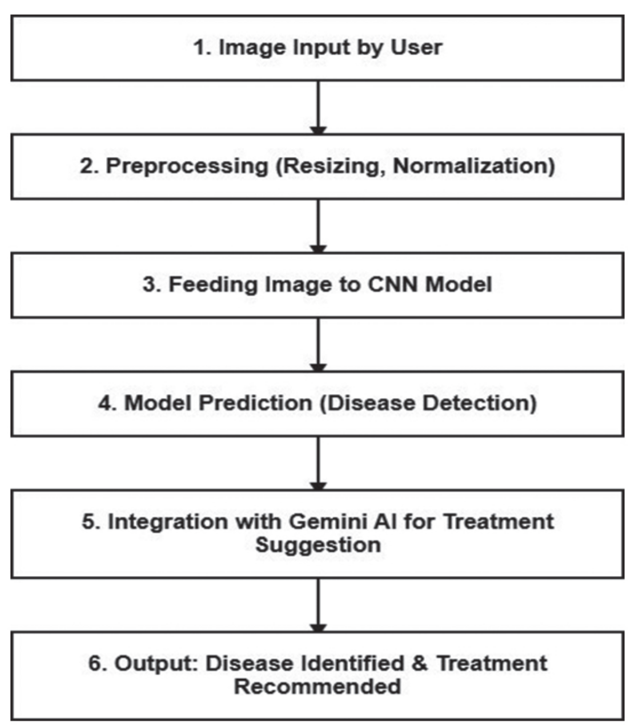

Figure 2. Plant disease detection flowchart.

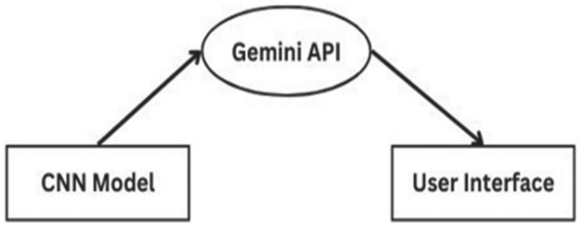

Figure 3. Google GenAI interaction diagram.

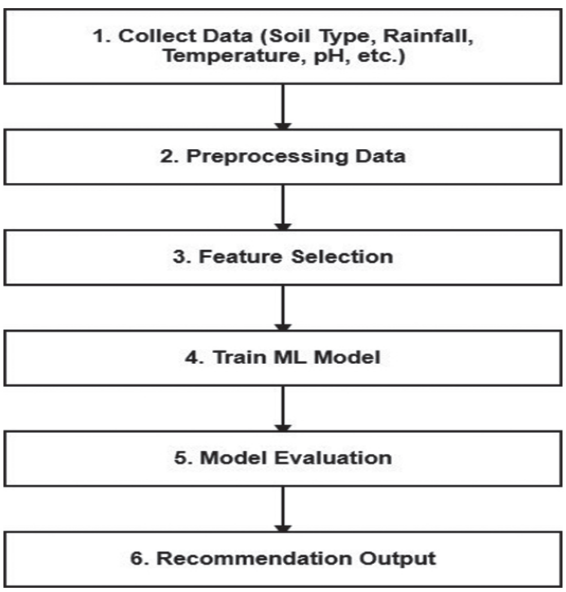

Figure 4. Machine learning model training process.

IV. ANALYSIS

The plant disease identification model, which was constructed with Tensor Flow, obtained an accuracy of 92%, demonstrating its capacity to identify common plant illnesses from uploaded photos. The system worked well for diseases with adequate training data, but had reduced accuracy for uncommon diseases due to the scarcity of pictures available for these situations. One of the issues encountered during model construction was a class imbalance in the dataset, which led the model to be biased toward more commonly occurring illnesses. This problem was solved by utilizing data augmentation and oversampling techniques.

In the majority of situations, using Google Generative AI to give therapy recommendations for discovered disorders was successful. After detecting the ailment, the algorithm recommended appropriate treatments, which were often consistent with professional agricultural recommendations. However, several people proposed that the advice be more tailored to reflect the distinct agriculture methods of various locations. This will guarantee that treatment recommendations are more precise and practicable for farmers in varied geographic locations.

Overall, user feedback on the treatment suggestions was excellent, with users praising the help it provided for dealing with plant illnesses. The crop suggestion system, which considers environmental factors including soil type, moisture, temperature, and location, also gave useful information. By taking into account these parameters, the system recommended crops that were best suited to the user's conditions, resulting in higher agricultural yields. For example, it advocated maize for hotter climates and rice for locations with more water.

While the algorithm typically made correct suggestions, its dependence on manually supplied environmental data occasionally resulted in inaccuracies or less exact recommendations. Integrating real-time data, such as temperature, humidity and soil conditions might increase crop suggestions' accuracy and relevancy. This would eliminate human mistakes and allow for more flexible, data-driven judgments. Such integration would also improve disease prediction, crop recommendations and precision farming techniques.

Figure 5 shows the prediction accuracy of many models, including Decision Tree, Naive Bayes, SVM, Logistic Regression, Random Forest and XG Boost.

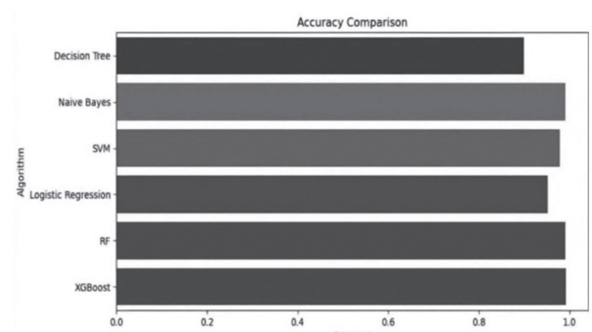

Figure 5. Accuracy of models.

Figure 6 shows the model predicting the illness of a leaf using the Random Forest, which has the highest accuracy.

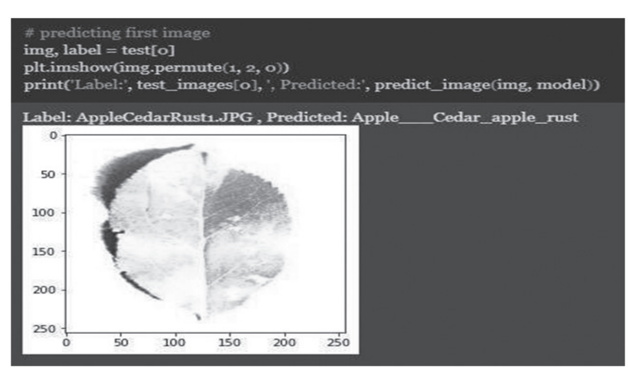

Figure 6. Plant disease result.

Figure 7 depicts the project's front-end and includes the solution, crop rotation time period and other crop and disease-related information.

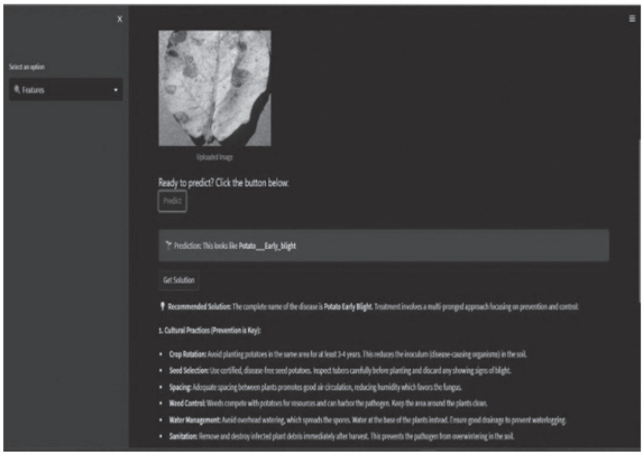

Figure 7. Predicting the plant disease.

However, there are still limits to the existing concept. While the plant disease detection method is generally accurate, it might benefit from a bigger and more diversified dataset, particularly for uncommon or developing plant diseases. Furthermore, the system's generalization skills might be improved by adding data from other places and climatic situations. In the future, using real-time environmental data from sensors or meteorological data might improve crop suggestions by making them more dynamic and customized to changing field circumstances.

V. FUTUREWORK

Potential improvements to PhytoMate include increasing the dataset's accuracy in disease identification, particularly for uncommon illnesses and varied plant species.

Integrating real-time environmental data via sensors or meteorological APIs will make the crop recommendation system more dynamic andaccurate. Additionally, creating a mobile app will improve farmers' accessibility by allowing them to simply submit photographs and obtain recommendations while on the road.

Adding features such as real-time AI-based pharmaceutical suggestion systems for crops after determining the ailment they are suffering from will save the farmer time and boost the crop's chances of survival, as numerous illnesses can ruin the whole crop on the farm.

VI. COMPARATIVE STUDY

Several methods for detecting plant diseases and recommending crops have been developed, each with differing capabilities. These systems use a variety of technologies, including machine learning, artificial intelligence, and environmental data, to provide agricultural solutions. The following is a comparison of various well-known systems, outlining their work, essential features, strengths and limitations.

PlantVillage: PlantVillage [17] is a project developed by Penn State University that uses deep learning (CNN) models for plant disease detection. It supports multiple plant species and provides accurate disease identification through a user-friendly mobile interface. However, it does not offer treatment advice or crop recommendations. The app helps farmers quickly diagnose plant diseases using image-based analysis.

PlantDoc: PlantDoc [18] is a publicly available dataset and research initiative aimed at plant disease classification using deep learning techniques. It includes diverse images of diseased and healthy plant leaves captured in real-world conditions, enhancing model robustness. Unlike PlantVillage, PlantDoc focuses more on dataset diversity and real-environment variability, which improves model generalization. However, it also lacks integrated treatment guidance or agricultural advice for farmers. Its primary strength lies in training and benchmarking deep learning models for field-level applicability.

SmartAgri: SmartAgri [19] is a system that combines IoT-based sensor data and AI to recommend crops based on environmental conditions. While SmartAgri provides valuable recommendations based on weather, soil, and other factors, it does not feature plant disease detection. SmartAgri also leverages machine learning models topredictoptimalplantingtimes and enhance yield forecasting.

Farmbot: FarmBot [20] is an automated farming system that integrates AI for both crop recommendations and plant disease detection. The system uses machine learning models to recommend crops and to detect plant diseases using image recognition techniques. FarmBot also utilizes IoT sensors for real-time environmental monitoring, ensuring optimal conditions for crop growth.

VII. CONCLUSION

The research paper explains the design and characteristics of a machine learning-based system for categorizing plant diseases. In this study, we created PhytoMate, a complete plant disease diagnosis and crop selection system that blends machine learning with Google's Generative AI (Gemini). PhytoMate uses TensorFlow for plant disease detection and integrates with powerful AI techniques to deliver not only precise disease forecasts, but also individualized crop suggestions depending on environmental and soil conditions. This dual capability distinguishes PhytoMate as a novel tool for farmers and agriculturalists, assisting them in optimizing crop productivity while minimizing plant diseases.

The system's primary features are its user-friendly interface, real-time suggestions and data-driven approach. However, it is vital to recognize the existing system's shortcomings, such as its dependency on internet connectivity and the need for additional improvement in illness detection under changing environmental circumstances. Future work will concentrate on strengthening these elements by including new data sources, boosting the system's predictive skills, and making it applicable to a broader range of crops. Overall, PhytoMate represents a hopeful step forward in modern agriculture, demonstrating how AI can be used to address crucial issues in plant health and farming efficiency. The system's continued development will strive for increased accuracy and accessibility, with the ultimate objective of making sustainable agriculture techniques more accessible to farmers throughout the world.

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Dr. Sandhya Avasthi (SM, IEEE) completed Ph.D in the area of Machine Learning and Text Mining from Amity University, Noida. She is an Associate Professor in the Department of Computer Science Engineering, ABES Engineering College, Ghaziabad, India. She did her M.Tech in Computer Science and Engineering from UP Technical University, Lucknow, and B.E. in Computer Science and Engineering from Dr BR Ambedkar University, Agra. She has over 19 years of teaching experience and is an active researcher in the field of machine learning and data mining. Her research interests include Natural Language Processing, Information Extraction, Information Retrieval, Data Science and Business Intelligence. She has published numerous research articles in refereed international journals, conference proceedings and book chapters. She is also contributing as a reviewer in Springer Journal (JIMS, JAIHC), IEEE conferences, Hindawi, and Aging International Journal. She is associated as a member ACM and is continuously involved in different professional activities along with academic work.

Dr. Shweta Roy, AMIETE, MIEEE is working as Senior Assistant professor (Selection Grade), Department of Computer Science and Engineering, ABESEC, Ghaziabad, UP. She did her B.Tech in Computer Science and Engineering from Magadh University, Bodhgaya, Bihar, India. She did her Masters in computer science and engineering from Abdul Kalam Technical University, Lucknow, UP. India.

She obtained PhD from Alfalah University, Faridabad, Haryana, India. She has over 19 years of teaching experience. She is doing her research in the field of deep learning algorithms to obtain new set of classifiers for the share market. She has zeal to teach new technologies and subjects. She has around 12 research papers published in national and international journals. She has also written book chapters in her research domain.

Devendra Kumar Misra is currently working as Assistant Professor, Department of Computer Science and Engineering, ABES Engineering College, Ghaziabad, UP, He received his B.Sc. (Math) from CSJMU, Kanpur in 2006, M.Sc. in Electronics from UIET, CSJMU, Kanpur in 2008 and Masters in Technology in Information Security from Guru Gobind Indraprastha University, New Delhi in 2010.

He received P.G. Diploma in Cyber Law from Indian Law Institute (Deemed University) in 2015. Currently he is pursing PhD from CSE department, NIT Patna. He has over 15 year teaching and research experience. Published five national and 15 international papers. He believes in seeking a responsible position that enables him to grow both on a professional and personal front, a position that utilizes his skills & abilities; while being resourceful, innovative and flexible.

Dr. Kadambri Agarwal is currently working a Professor in Computer Science and Engineering Department at ABES Engineering College, Ghaziabad, India. She received her Ph.D. in Computer Science and Engineering from Uttarakhand Technical University, Dehradun, India. She has more than 18 years of Teaching Experience.

She published over 30 research papers in SCI/ Scopus/Scopus indexed conferences including papers in ACM transactions and IEEE Transactions. She published five books besides various book chapters. Her area of interest is AI, Machine Learning, Applied Cryptography and Ad hoc Networks. She is an active member of ISC. She is also contributing as reviewer of various SCI journals and IEEE conferences.