DEPARTMENT OF AGRICULTURE DEVELOPMENT
& FARMERS' WELFARE, GOVERNMENT OF KERALA

FARM INFORMATION BUREAU

KERALA KARSHAKAN

THE FIRST ENGLISH FARM JOURNAL FROM THE HOUSE OF KERALA KARSHAKAN

OCTOBER 2025
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E-JOURNAL

The Climate-Smart Agriculture:

HOW TECHNOLOGY IS SECURING OUR FUTURE

INSIDE

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THE FIRST ENGLISH FARM JOURNAL FROM THE HOUSE OF KERALA KARSHAKAN

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HARNESSING TECHNOLOGY FOR SUSTAINABLE FARMING

Agriculture is the backbone of Kerala, supporting livelihoods, food security, and the state's cultural heritage. Farmers face persistent challenges such as crop diseases, pests, unpredictable weather, and limited land. Traditional practices, though valuable, are often insufficient to address these issues. Emerging technologies like Artificial Intelligence (AI), drones, and Internet of Things (IoT) are transforming agriculture by enabling early detection of pests and diseases, efficient resource management, and informed decision-making. These tools act as early warning systems, helping farmers protect their crops and improve yield quality.

Climate-smart and precision agriculture are bridging the gap between innovation and traditional farming. AI-based apps, drones, and smart irrigation systems allow farmers to monitor crops, detect disease outbreaks, and optimize water and fertilizer use. Controlled Environment Agriculture and smart greenhouses, powered by IoT and AI, create favorable growth conditions, enabling year-round production and higher-quality yields. Such technologies not only reduce costs and waste but also promote sustainable practices that safeguard soil health, conserve water, and reduce environmental impact.

The adoption of these technologies strengthens farmers' resilience against climate and economic uncertainties. Kerala's diverse crops—from vegetables and fruits to spices and coconuts—benefit from AI-assisted monitoring, predictive models, and smart cultivation practices. Collaboration among research institutions, extension services, and farmers ensures that innovations are practical, accessible, and farmer-friendly. By combining traditional knowledge with modern technology, Kerala's agriculture can achieve higher productivity, sustainability, and profitability, securing a resilient future for the farming community.

Artificial Intelligence in Crop Disease Detection- Early Warning systems for **Pest and Disease Management**

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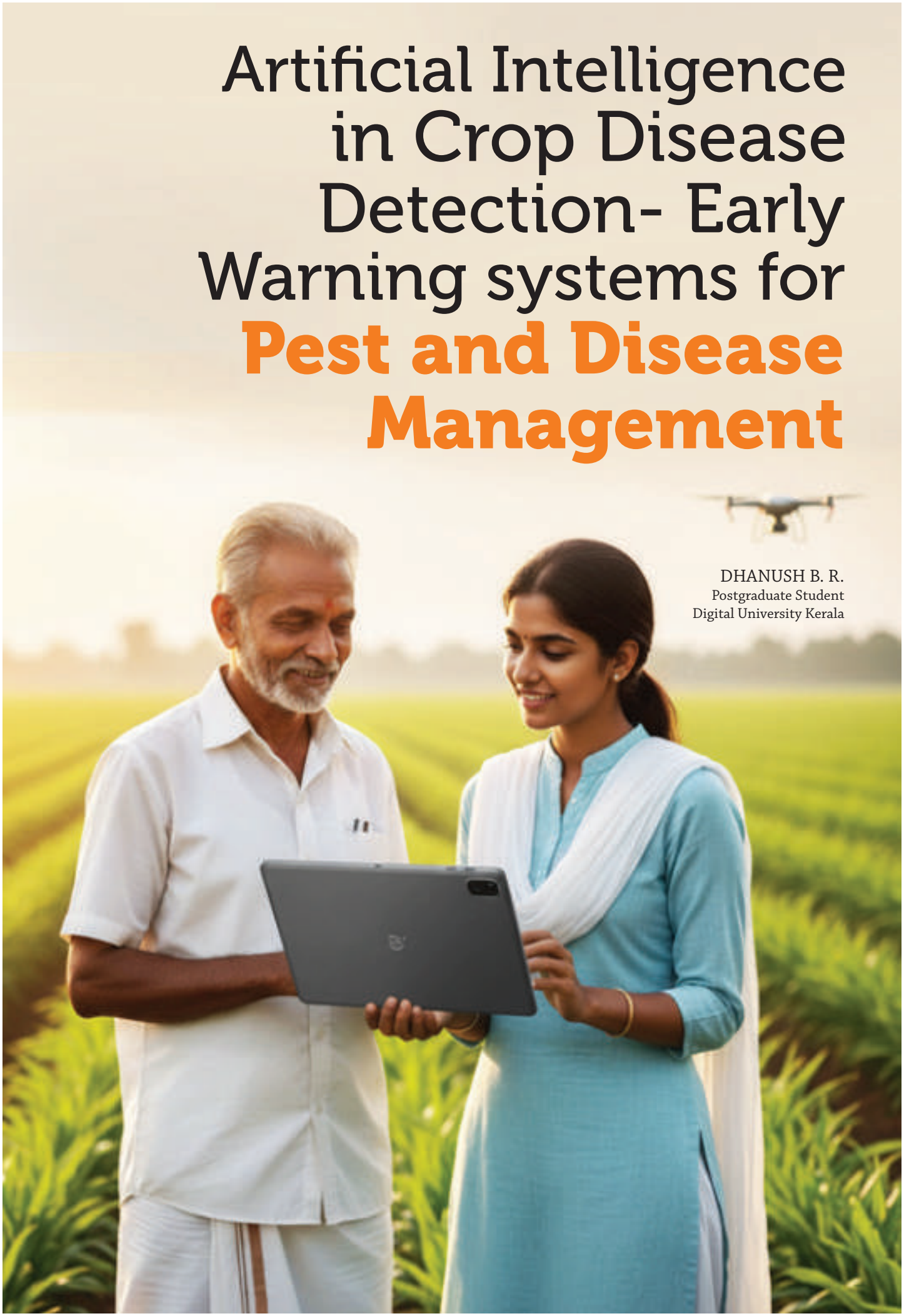


Agriculture remains the backbone of Kerala's economy, livelihood and food security. Farmers give their time, labour, and effort to raise quality crops, but even with proper practices, pests and diseases are a constant challenge. They not only cut down yields but also impact the quality of the crops, resulting in massive economic losses. As estimated by the Food and Agriculture Organization (FAO), almost one-fifth to two-fifths of the world's crop production is lost because of pest attacks and disease epidemics. For a farmer, even a minimal level of yield loss could be extremely costly. Conventionally, detection of crop diseases has been based on experience, laboratory tests, and visual observations. Yet, such techniques are typically time-consuming and can detect disease only after it has already inflicted a lot of damage. This is where contemporary technologies like artificial intelligence (A.I.) are revolutionizing the agricultural industry. Farmers can now anticipate, identify, and control diseases considerably with technologies like drones, mobile apps, and remote sensing. AI based methods guarantee that farmers can protect their harvests before the situation worsens by acting as early warning systems.

Artificial Intelligence can be defined as the ability of the machines to identify and learn from the underlying patterns present in the data and make decisions that resemble how humans think. AI can process enormous volumes of data in agriculture, such as photos of plants, weather reports, or information about the health of the soil, in a fraction of the time it would take a human expert.

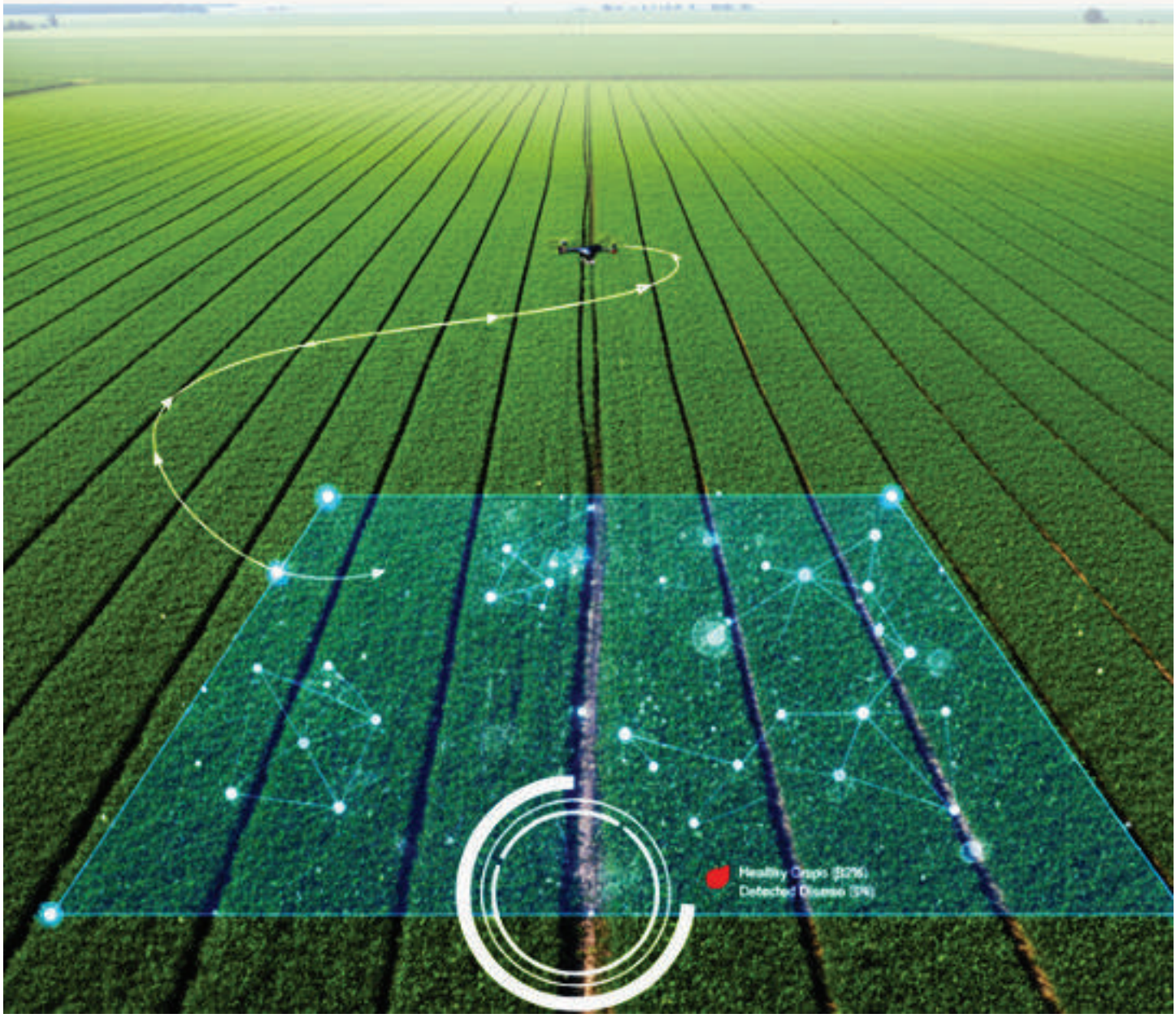
There are multiple AI techniques having specialized applications. Machine learning, for example can be used to analyze previous disease outbreaks and climatic records to forecast upcoming outbreaks. With computer vision, farmers can identify symptoms on leaves, stems or fruits just by uploading a photo from their smartphone. Deep learning algorithms also get more accurate with time as they are trained on an increasing volume of data from different agri-environments. In addition, AI systems can combine data from satellites, drones, and terrestrial sensors, thus providing a better overview of crop health.

The operation of AI-based early warning systems can be explained in three broad phases. The first is data gathering where images are gathered by farmers or extension agents using mobile phones, drones or satellites, and field sensors capture temperature, humidity, and soil moisture. Previous outbreaks' data is also stored and retrieved. During the second phase, this data is worked through by AI algorithms that examine photos and weather data in order to identify the earliest stages of disease. A picture of a barely off-coloured leaf, for example, might be cross-referenced with thousands of archived

images of plant diseases so that the system can determine if the symptom of the leaf being off-colour is indicative of fungal or bacterial infection. In the third stage, which involves communication of results and advice, the system notifies the farmer of an impending danger, frequently right on their mobile device. Based on the current weather , the alert might state that there is a very high chance for the occurrence of a specific disease in the coming weeks. In addition to the diagnosis, farmers are given detailed advice on preventive measures, which can include anything from biological control and cultural practices to the careful application of chemicals upon requirement These systems guarantee a shift from a reactive strategy, where pesticides are applied after damage is observed, to a preventive strategy, in which remedies are put in place prior to the disease having a significant impact on the crop.

For farmers, the advantages of such technology are real. Early detection of diseases in crops enables them to intervene before infestation spreads far, saving them up to one-third of their yield loss potential. Because interventions become focused, the quantity of chemicals required is significantly lowered, reducing the cost of production and preventing pesticide residues from penetrating food chains or the environment. Decisions are informed by science recommendations instead of speculation, which makes farmers confident in their decisions. The accessibility of such systems is also very significant. Most of the AI- based applications nowadays are made simple enough for people to use, supported by local languages and accessible on basic phones. This implies that small farmers in distant villages can also access these services without huge investment.

Kerala's agriculture is unique because it produces a wide variety of crops, including vegetables, rice, bananas, coconuts and spices. These crops have



enormous commercial and cultural value, but they are also very vulnerable to pest and disease attacks. Here, AI can be extremely helpful. Drones with cameras can identify diseases like bud rot in coconut and arecanut before they turn out to be serious. While AI-based monitoring in banana plantations can promptly detect Sigatoka leaf spot, predictive models can be used to anticipate stem borer outbreaks in rice fields. Similarly, vegetable and spice growers can use AI-enabled smartphone apps to snap pictures of affected plants, allowing them to quickly differentiate between actual disease infections and nutrient deficiencies.

In this ecosystem, Krishi Vigyan Kendras (KVKs), agricultural institutions, and research stations could collaborate as knowledge partners. Community-wide action can be taken to stop infections before they spread by utilizing AI techniques and sending location-specific notifications at the Panchayat or farmer group level.

India's and other countries' successes give people faith in AI's potential. Farmers in India are already using apps like Plantix and Nuru, which allow them to take a picture of their leaves and instantly identify the disease and provide guidance on what to do. AI-powered technologies have assisted in the detection of the cassava mosaic virus in number of African countries, averting enormous yield losses. Pilot projects to combine machine learning models with weather forecasts to alert farmers of potential pest hazards in rice cultivation have already started in Kerala. These examples serve as a reminder that artificial intelligence is a reality and not just a pipe dream.

Though the potential of AI is promising, challenges cannot be ignored. The biggest bottleneck is the quality of datasets, particularly disease images and Kerala's crop and climatic condition-specific records, poor connectivity and an absence of smartphones in many rural areas in real-time use are common issues. Awareness is also an issue, as there are likely to be farmers who will be hesitant to use a technology with which they have no familiarity. Sophisticated AI-driven technologies such as drones and IoT sensors can also be out of pocket for some because they are more expensive, unless cooperative ownership schemes or subsidies are encouraged.

In future, efforts are required to expand training and trust-building among farmers. For models to be widely accepted and useful to Kerala's ecosystems, they must be localized both linguistically and scientifically. Partnerships between the public and private sectors can be useful in scaling these solutions at a reasonable cost. Above all, AI must be practical and farmer-friendly, enhancing rather than replacing farmers' knowledge and expertise.

In the fight against crop pests and diseases, AI is emerging as a potent tool for farmers, researchers and policymakers. AI offers early warnings and serves as a digital companion for ongoing crop monitoring in Kerala, where agriculture is essential to both food security and culture. AI closes the gap between science and practice by combining local knowledge with data-driven accuracy , guaranteeing targeted protection and minimizing losses. By combining cutting-edge innovations with traditional methods, this technology promotes sustainable farming. So, rather than abandoning traditional methods, the future of agriculture lies in refining them with the intelligent support of modern technology.

Links:
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2. https://plantix.net/en/

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The Climate-Smart Agriculture: How Technology is Securing Our Future

Image source: Eastern Peak (https://s9.easternpeak.com)

Image source: Aeronerve (https://aeronerve.my)

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The farmers around the world are facing a climate crisis that threatens global food security and their livelihoods. The unpredictable weather conditions, droughts, and decreasing water supplies are not just warnings, but they are directly influencing the harvests and rural economies today. The population is increasing day by day with increasing demand for food, which is outpacing the available land and resources, which is pressuring agriculture to provide more with the limited resources. Amid these challenges, climate-smart agriculture has emerged as a transformative solution since it harnesses data-driven technology and innovation to build sustainable food systems for the future. In 2025, climate-smart agriculture is expected to boost crop resilience up to 30% across India. Farmers are rewriting scarcity into adaptation, efficiency, and hope by integrating real-time monitoring and precision farming. This solution blends tradition with innovation, which empowers the growers to optimize resource use, safeguard soil health, and adapt to a constantly changing world.

What Is Climate-Smart Agriculture?

Climate-smart agriculture is basically built on three key principles: sustainability, productivity, and resilience. Sustainability means using different farming methods that protect the natural resources, such as planting drought-tolerant crops, improving soil health by following organic farming, and using irrigation systems like drip irrigation for minimizing the resource wastage. Productivity is concerned with increasing crop yield with the limited land area without harming the environment through crop diversification, integrated nutrient management, etc. Resilience means strengthening farming systems so that they can withstand climate challenges, which include growing climate-resilient crops, and conserving biodiversity through agroforestry and mixed farming.

The major problem with traditional agriculture is that it often relied on manual monitoring, leading to unpredictable yields and resource wastage. Climate-smart agriculture approaches combination of traditional knowledge and new technology, i.e., real-time sensors and early warning systems, to help farmers make smarter decisions and adapt quickly to changing weather, pests, etc. This helps in securing food supplies, increasing farm income, and reducing risks, which indirectly makes agriculture more robust for the future.

How Sensor Networks Work?

In climate-smart agriculture, sensor networks are composed of different sensors placed across the field to collect important data about the environment and crop health. These include temperature sensors for gauging ambient conditions, humidity sensors for air moisture, soil moisture sensors to determine irrigation requirements, pH sensors to assess soil acidity, nutrient sensors for soil fertility, and plant health sensors that may use imaging or optical technology.

Each sensor is connected to a central microcontroller, that collects data from the sensors, processes the signals, and transmits the information wirelessly using protocols. Sensors are distributed in the field in such a layout that ensures representative sampling of conditions. For example, soil moisture probes are buried at different depths and locations throughout the field.

Sensor data from the field is sent to a gateway device, like a Raspberry Pi or a base station, which gathers all the information and uploads it to the cloud or a server. Farmers can then use a web or mobile dashboard to see live updates about temperature, soil conditions, and moisture levels, all shown through easy-to-read charts and maps.

Benefits of real-time monitoring

Real-time monitoring with IoT-based smart agriculture systems offers substantial benefits, which is playing a key role in transforming how farms operate globally. These systems provide continuous and efficient monitoring of parameters such as soil moisture, crop health, weather patterns, etc. Automated monitoring reduces the need for manual labour, automate daily work, and ensures that crops receive only the adequate quantity of resources at the appropriate time. Precise application of water, fertilizers, and pesticides minimizes input costs while increasing yield and further reducing labour expenses due to automation. Real-time monitoring helps to identify problems like disease outbreaks, pest infestations, and nutrient deficiency which enables timely intervention and prevention of crop loss. The data collected offers insights for making decisions about irrigation schedules and fertilizer application. These decisions are often backed by predictive analytics and data visualization tools. Such systems optimize resource use, lower water consumption, reduce runoff and emissions, and promote soil health, thereby supporting sustainable farming. Farms utilizing real-time monitoring have demonstrated increased yields due to timely data-driven management responses. These systems enhance transparency in the food supply chain by allowing tracking of crops and livestock from production to distribution, thereby building consumer trust. Real-time alerts for extreme weather, pests, or diseases allows farmers to take preventive actions that help minimize losses and variability in production.

Technological innovations

These are transforming climate-smart agriculture by harnessing advanced digital tools for greater efficiency, resilience, and sustainability. Some of the key innovations include:

The Climate-Smart Agriculture: How Technology is Securing Our Future

● PRECISION AGRICULTURE & DATA-DRIVEN FARMING:

GPS-guided machinery, drone-based remote sensing, satellite imagery, IoT-enabled sensors, and big data analytics enable site-specific management of crops, soils, and resources, increasing efficiency and reducing inputs, waste, and environmental impact. Real-time data collection from soil and weather sensors allows for continuous monitoring and precise resource application, thereby boosting crop yields by up to 30%.

● ARTIFICIAL INTELLIGENCE (AI) AND REMOTE SENSING:

AI-powered models predict weather, disease outbreaks and optimize irrigation schedules. Remote sensing technologies like satellites and drones provide high-resolution real-time monitoring of crop health, soil moisture, and pest outbreaks. This helps farmers make timely and accurate interventions and adapt to changing weather patterns.

● IOT INTEGRATION:

Networks of IoT-enabled devices, including weather stations, soil probes, livestock trackers, and automated irrigation valves, collect instant field data, supporting timely decisions for irrigation, fertilization, and pest control. IoT systems promote sustainable water and nutrient use, improve traceability, and even enhance animal welfare through real-time monitoring.

● BLOCKCHAIN TRACEABILITY:

Blockchain-based management platforms securely create transparent records from farm to fork, strengthening consumer trust and enhancing supply chain integrity, especially in times of environmental or economic shocks.

● BIOTECHNOLOGY:

Biotechnology reduces chemical use and enhances ecological balance, including crop breeding for drought and pest resistance and the development of eco-friendly fertilizers and pest repellents.

● REGENERATIVE AGRICULTURE & CARBON SEQUESTRATION:

Practices such as agroforestry, incorporating organic amendments, and minimum tillage restore soil health, boost carbon sequestration, and support long-term fertility.

THE CHALLENGES OF SENSOR-DRIVEN AGRICULTURE

It requires high investment for purchasing and installing sensors, along with the setting up of monitoring systems, which can be a barrier for small and medium-sized farmers. In rural areas, it's difficult to get good internet and network access. This makes it difficult to consistently monitor real-time data. Managing large amount of such data from sensors requires both technical skills and secure storage to protect sensitive farm information from breaches. Farmers must be properly trained to interpret sensor data accurately and utilize technology effectively for making accurate decisions regarding farm management.

FUTURE PROSPECTS OF SENSOR-DRIVEN AGRICULTURE

Sensor-driven agriculture holds huge potential to revolutionize farming in the coming years. The integration of AI-driven predictive analytics will enable active decision-making, helping farmers predict weather patterns, pest outbreaks, and nutrient deficiencies before they become problems which cause huge economic loss. Advances in connectivity will ensure faster and more reliable data transmission even in remote farm locations. Future prospects also include enhanced sustainability with real-time monitoring of carbon footprints and resource use, promoting climate-resilient farming practices. Blockchain technology will improve transparency and traceability throughout supply chains, increasing consumer confidence and reducing fraud. These technological advances are becoming increasingly affordable and accessible, empowering small holder farmers alongside large agro-enterprises. By embracing sensor-driven smart agriculture, the farming community worldwide can enhance productivity, adapt to climate challenges, and contribute to global food security in a sustainable manner.

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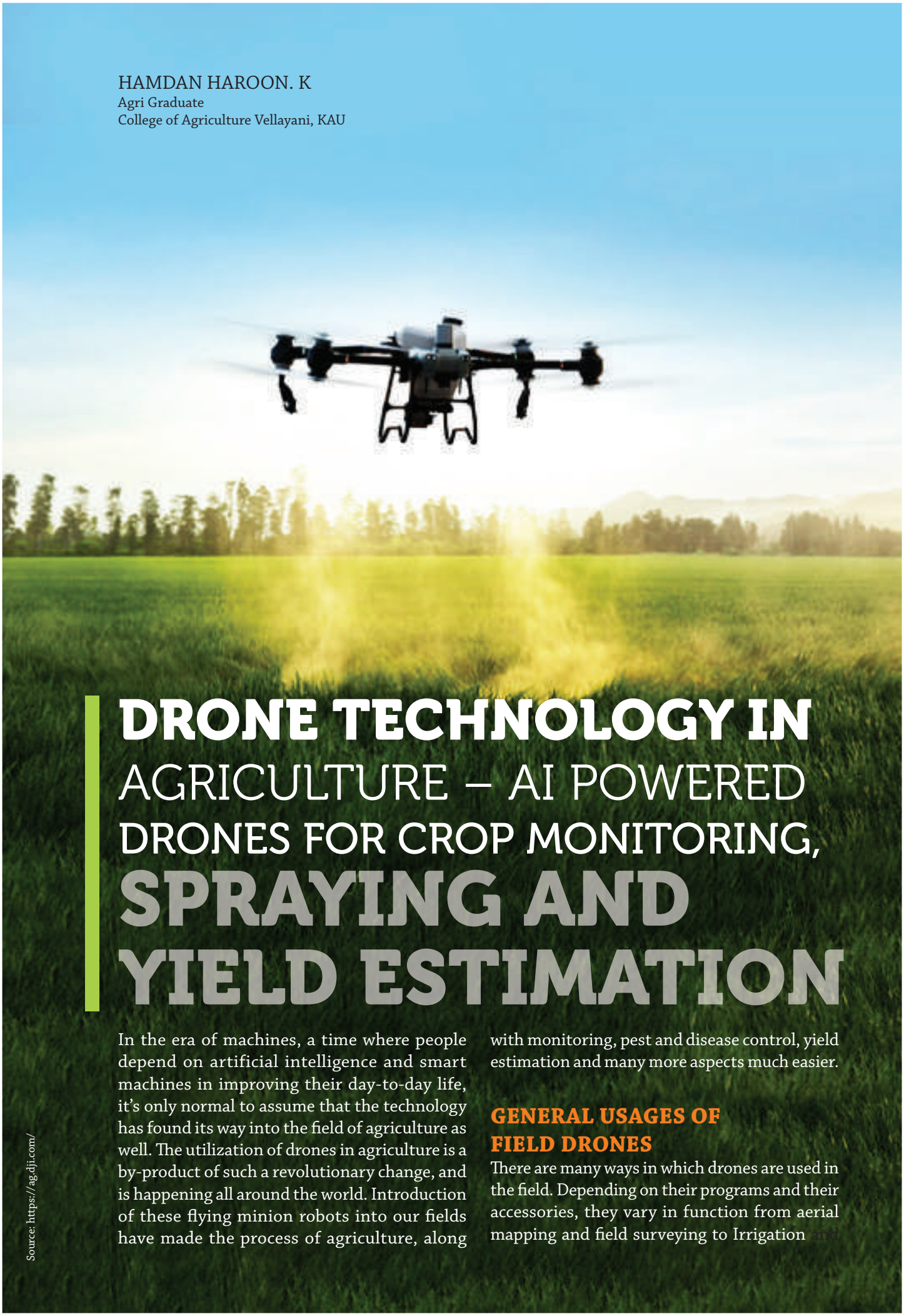

DRONE TECHNOLOGY IN AGRICULTURE – AI POWERED DRONES FOR CROP MONITORING, SPRAYING AND YIELD ESTIMATION

In the era of machines, a time where people depend on artificial intelligence and smart machines in improving their day-to-day life, it's only normal to assume that the technology has found its way into the field of agriculture as well. The utilization of drones in agriculture is a by-product of such a revolutionary change, and is happening all around the world. Introduction of these flying minion robots into our fields have made the process of agriculture, along with monitoring, pest and disease control, yield estimation and many more aspects much easier.

GENERAL USAGES OF FIELD DRONES

There are many ways in which drones are used in the field. Depending on their programs and their accessories, they vary in function from aerial mapping and field surveying to Irrigation and

Source: https://ag.dji.com/

Water management. Leading countries in this fields include India, China, Japan and USA, each having different series of drones which are utilized by large scale farmers and agriculture-based companies worldwide. Companies such as Garuda Aerospace and Skylark drones supply drones in India, whereas big companies such as Yamaha & DJI drones are used in a much larger scale across the world. These drones are mainly used for tasks such as mapping of certain field areas, crop monitoring & health analysis, fertigation & spraying of pesticides and herbicides, Irrigation & water management and soil & field analysis. Drones are also used in various government insurance schemes such as Pradhan Mantri Fasal Bima Yojana (PMFBY) to facilitate accurate and timely crop loss assessment, which is a crucial factor is settling claims.

WHAT MAKES THEM BETTER THAN OUR CONVENTIONAL PRACTICES?

The proper utilization of this technology helps the farmer reduce his labor cost by a considerable amount. Since the drones are programmed to do their part, all it requires is a skilled operator who can supervise the operations of the drones. They are also very efficient compared to manual labor. Be it spraying of fertilizers, pesticides or herbicides, they spray a constant volume, and it reaches all the areas of the field equally without fail. It also helps with reducing wastage of materials that usually happen as part of human error. Compared to the time it takes to cover an area of land, these drones are significantly faster as well. In short, using drones to carry out cultivation operations such as pest and disease detection, spraying, analysis of possible disease patterns and yield estimation delivers a much faster and accurate result, with little to no room for errors.

CURRENT SCENARIO IN INDIA AND KERALA

Even though this technology is relatively new, people and various organizations have picked up on its benefits, and are utilizing its potential for a better precision agriculture practice. Government of India has schemes such as PM Kisan Drone Yojana, which comes under the Sub-Mission on Agricultural Mechanization (SMAM) and Namo Drone Didi, which helps women led self-help groups by equipping them with drone technology to provide agriculture services. In Kerala, various demonstrations and training classes have been conducted under KVKs, which has been helpful in increasing the popularity of drone-based agriculture among farmers. For small scale farmers who can't afford drones, there are even public and private organizations which help in lending the drone service on command. On a global level, this technology has gained its popularity well enough that most of the million-dollar agriculture-based companies consider this technology as a very big asset in managing their fields and managing their revenue.

Source: Getty Images

MAIN ADVANTAGES

Introduction of drone technology into agriculture has made significant impacts. Big ones to speak of is efficiency. Usage of drones in completion of irrigation, spraying of pesticides and herbicides or even aerial monitoring has led to an increased speed and accuracy, thereby resulting in the boosted efficiency of the farming cycle. While the initial cost of establishment being high, in the long run, these machines prove to be much more cost effective as well. Not to mention the reduction of crop damages from the early recognition of pest attacks and disease patterns along with the adequate application of control measures. They also contribute to the safety of the farmers as well, up to some extent.

Source: https://botsanddrones.in/agriculture-drones/f/drone-technology-in-agriculture

CHALLENGING ASPECTS

e first challenge to speak of is the initial cost. Although they are lucrative in the long run, the establishment cost of a drone system with its full capacity is relatively higher, which might not be affordable to small to medium scale farmers. Also, the operation and maintenance of these drones require the presence of a skilled operator, and it might come in the way for certain farmers. In the case of larger fields, the battery life of the drones could also pose some challenges. Some regulatory issues might also be there, such as the aviation rules and the DGCA (Directorate General of Civil Aviation) regulations. Above all, he biggest challenge in this is our weather and climate. A clear and good weather is essential for the maximum efficiency work of these drones.

FUTURE POTENTIAL

The future holds so much for the drone technology. Since AI is evolving at a very high speed, and technologies and machines following up not so far behind, the possibilities for future upgrades to this technology can be seen in the immediate future. Potential of introduction of self-diagnostic drones or integrating multiple drones in creating a swarm system, or even building an ecosystem of drones and ground robots in a high efficiency field management are all sides of the vast future waiting for the drone technology, especially in a rapid growing country such as India.

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Smart Greenhouses – IoT and AI for controlled **environment agriculture.**

INTRODUCTION

Farming has always been a balancing act between nature and human effort. But in recent decades, challenges like unpredictable weather, water shortages, shrinking farmland, and a rapidly growing population have made that balance harder to maintain. The United Nations projects that by 2050, the world will need to produce nearly 70% more food than today. Traditional farming methods, tied closely to natural cycles, may not be enough to meet this demand.

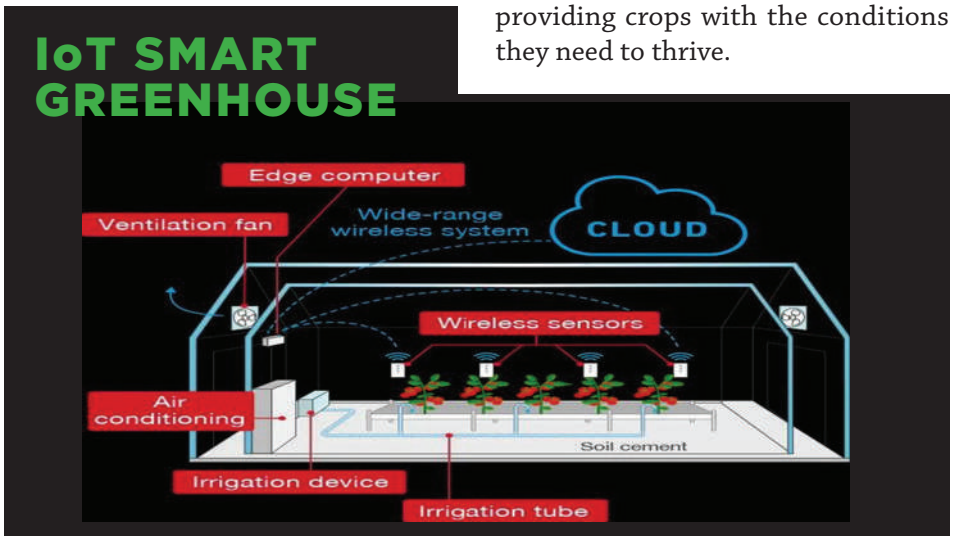
This is where Controlled Environment Agriculture (CEA) comes in. CEA allows crops to be grown in spaces where light, temperature, humidity, and nutrients can be carefully managed. Within this domain, smart greenhouses stand out because they use advanced digital technologies like the Internet of Things (IoT) and Artificial Intelligence (AI). Together, these tools create highly efficient systems that can monitor, predict, and even make decisions to support plant growth.

WHAT MAKES A GREENHOUSE "SMART"?

Traditional greenhouses already give crops some protection by trapping sunlight and shielding plants from harsh weather. However, they still rely heavily on farmers to adjust water supply, manage ventilation, or control pests. A smart greenhouse takes this a step further. By installing sensors, automated systems, and AI-driven software, the greenhouse can:

- Keep track of soil moisture, air temperature, humidity, and nutrient levels in real time.
- Automatically adjust lighting, irrigation, or shading when conditions shift.
- Alert farmers through mobile apps if something unusual happens.
- Learn from past data to improve crop cycles.

Instead of the farmer having to constantly react, the greenhouse becomes a self-regulating environment, providing crops with the conditions they need to thrive.



THE ROLE OF IOT – CONNECTING EVERY ELEMENT

The Internet of Things is essentially the nervous system of a smart greenhouse. Tiny sensors and devices act like eyes and ears, collecting information and sharing it through a connected network.

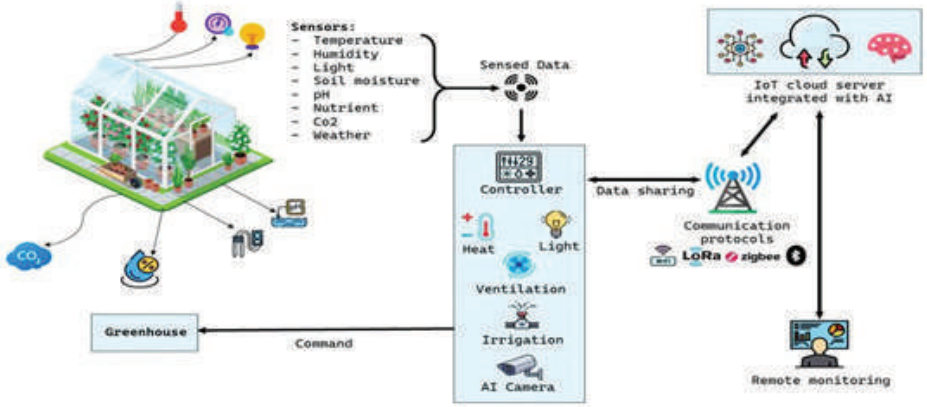


Image: Diagram showing IoT and AI integration in greenhouse management.

SOME OF THE KEY CONTRIBUTIONS OF IOT INCLUDE:

1. Constant Monitoring – Data about temperature, humidity, light, and soil quality is gathered 24/7.

2. Automated Controls – Devices adjust fans, sprinklers, or lights without waiting for human input.

3. Remote Access – Farmers can use smartphones or computers to check conditions and make changes from anywhere.

4. Predictive Alerts – IoT systems warn about equipment issues before they become serious.

5. Weather Integration – Greenhouses can adapt based on external weather forecasts, such as preparing for a sudden heatwave.

Example: *In a strawberry greenhouse, IoT-enabled irrigation ensures that water flows only when moisture levels dip below a safe limit, saving resources and preventing overwatering.*

THE ROLE OF AI – TURNING DATA INTO SMART DECISIONS

If IoT provides the data, AI gives it meaning. By using machine learning and computer vision, AI can analyze patterns, make predictions, and even suggest interventions.

Some powerful AI applications in smart greenhouses include:

- Predicting growth cycles so farmers know the best time to harvest.
- Recognizing plant diseases early by scanning images of leaves.
- Fine-tuning climate control to match the specific needs of each crop.
- Reducing energy costs by optimizing heating and lighting schedules.
- Forecasting yields to help with market planning and supply chains.

Example: *AI-powered cameras can identify tiny spots on cucumber leaves that signal fungal infection, giving farmers a chance to act before the disease spreads widely.*

BENEFITS OF SMART GREENHOUSES

Adopting smart greenhouse technology comes with a wide range of benefits:

1. Bigger and Better Harvests – Crops grow faster and more uniformly in controlled conditions.
2. Efficient Resource Use – Smart irrigation cuts water use dramatically, while precise nutrient delivery avoids waste.
3. Year-Round Farming – Crops are no longer dependent on seasons or weather changes.
4. Less Manual Work – Automation reduces the need for constant supervision.
5. Environmentally Friendly – Targeted use of fertilizers and pesticides lowers ecological impact.
6. Data-Backed Decisions – Farmers can improve practices based on detailed records from past seasons.

CHALLENGES AND DRAWBACKS

Even with its promise, smart greenhouse farming isn't without hurdles:

- Cost Barriers – Installing sensors, AI systems, and climate control units can be expensive.
- Learning Curve – Farmers need training to operate and maintain high-tech equipment.
- Cybersecurity Risks – As with any connected system, hacking or technical failures are possible.
- Energy Demand – Automated systems require steady electricity, making renewable energy integration essential.
- Access Inequality – Large agribusinesses adopt it faster than small farmers due to affordability issues.

LOOKING AHEAD – THE FUTURE OF SMART GREENHOUSES

The future looks bright as digital agriculture continues to advance. Some likely trends include:

- 5G Networks & Edge Computing
- Faster, real-time responses without relying fully on cloud servers.
- Solar-Powered Greenhouses – Reduced energy costs and carbon footprint.
- Blockchain Integration – Improving food traceability and consumer trust.
- Robotic Assistance – Machines that can sow, harvest, and monitor crops.
- AI Market Insights – Systems that not only grow crops but also suggest which ones will be most profitable.

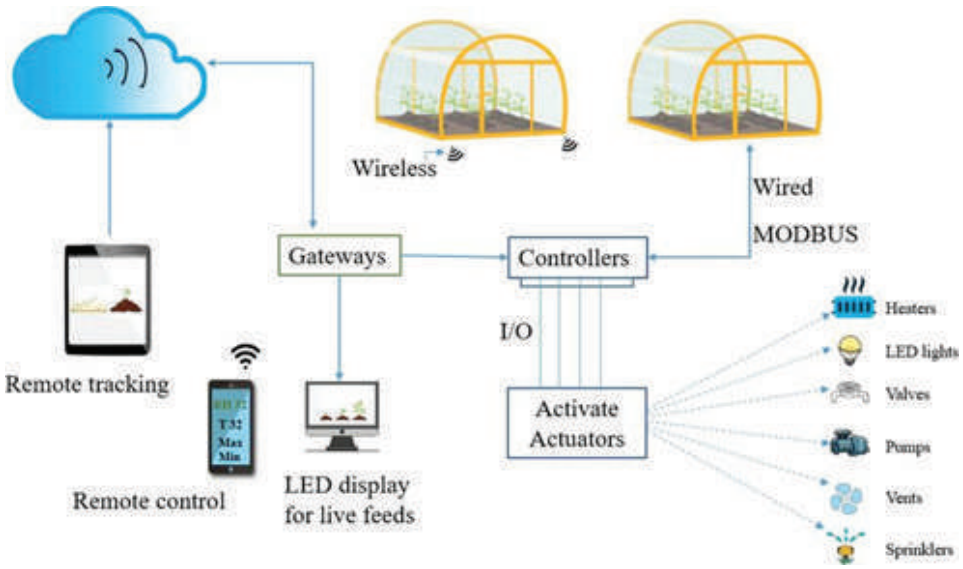


Image: Architecture of an IoT-empowered smart greenhouse showing feedback loops.

CONCLUSION

Smart greenhouses combine centuries-old farming wisdom with today's most advanced technologies. By linking IoT's real-time sensing with AI's predictive intelligence, these systems create farming environments that are more resilient, sustainable, and productive.

While high costs and technical challenges remain, ongoing innovation and broader adoption will make smart greenhouses more accessible over time. For farmers, this means greater stability and profitability; for society, it offers a pathway to secure food supplies & protect natural resources

In short, smart greenhouses are not just futuristic farms they are a practical step toward feeding the world sustainably.

IOT-BASED SMART IRRIGATION SYSTEMS

Precision Water Management using Soil Moisture and Weather Sensors

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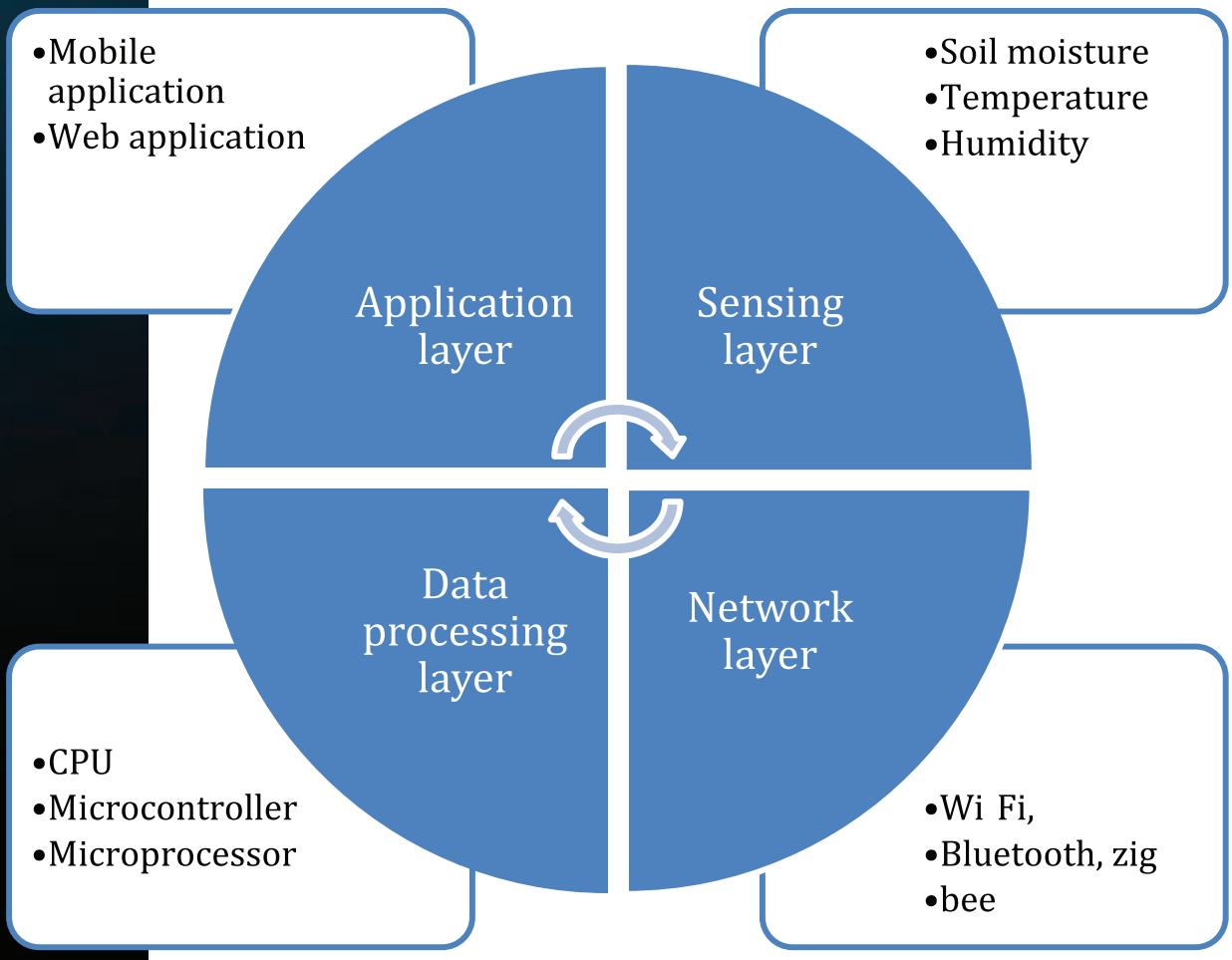
INTRODUCTION

Agriculture is the backbone of India, and in states like Kerala, it is deeply connected to people's culture, livelihood, and food security. However, farmers often face challenges due to unpredictable rainfall, depleting groundwater, and inefficient irrigation practices. Water is life for crops, but using it wisely is equally important. This is where Internet of Things (IoT)-based smart irrigation systems come into play. IoT-based smart irrigation combines soil moisture probes, weather sensors, IoT controllers, and cloud analytics, enabling precision irrigation that reduces water use, improves yields, lowers costs, and increases climate resilience. Systems combine simple sensors with modern technology to ensure crops receive the right amount of water at the right time.

HOW DOES A SMART IRRIGATION SYSTEM WORK?

Imagine a farmer's field equipped with tiny devices placed in the soil and in the open air. These devices are sensors that measure soil moisture, rainfall, temperature, and humidity. The data collected is sent to a controller or even directly to the farmer's smartphone through cloud platforms. Based on this information, the system can decide whether to switch on the irrigation pump or not. This reduces guesswork, avoids overwatering, and prevents crop stress due to lack of water.



1. SENSING LAYER

This layer includes different types of sensors that detect and measure changes in the surrounding environment. Sensors can capture data such as soil moisture, light, temperature, pressure, and motion. It acts as the foundation of IoT, as accurate sensing is necessary for further processing.

2. NETWORK LAYER

Once data is collected, it needs to be transmitted to other devices or systems. The network layer handles this communication using technologies like Wi-Fi, Bluetooth, Zigbee, LoRa, Z-Wave, and cellular networks. It ensures the smooth transfer of information from sensors to processing units.

3. DATA PROCESSING LAYER

This layer analyzes the raw data received from the sensors. It interprets the information, stores relevant records, and makes decisions accordingly. In some systems, it also uses previous data to improve predictions and enhance user experience. This layer plays a key role in converting raw information into actionable insights.

4. APPLICATION LAYER

The final layer presents the processed data in a way that can be understood and used by end-users. It delivers services such as mobile apps, dashboards, or alerts that support decision-making in various domains. This layer ensures that IoT devices provide meaningful and practical outcomes.

BLOCK DIAGRAM

SOIL MOISTURE SENSOR

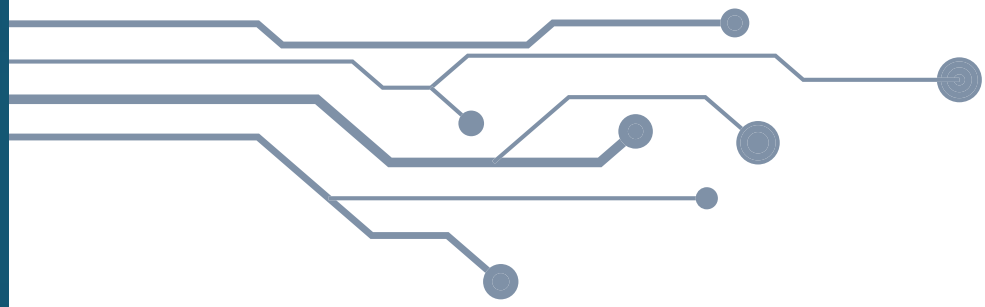
BLOCK DIAGRAM

- Soil moisture sensor
- Weather Sensors (Temp, Humidity, Rain)
- Microcontroller / IoT Node (Arduino, ESP32, Raspberry Pi)
  - Cloud Server /Mobile App
  - Irrigation system

SOIL MOISTURE SENSOR

- Measures the water content in the soil.
- Common type: Capacitive Soil Moisture Sensor.
- Ensures irrigation is triggered only when the soil is dry.

SOIL MOISTURE SENSOR



WEATHER SENSORS

- TEMPERATURE SENSOR:
(e.g., DHT11, DS18B20): Helps estimate crop evapotranspiration.

- HUMIDITY SENSOR:
(e.g., DHT11, DHT22): Indicates air moisture, influencing irrigation needs.

- RAIN SENSOR:
Detects rainfall to stop irrigation when nature provides water.

MICROCONTROLLER / IOT NODE

EXAMPLES:
Arduino, ESP8266/ESP32, Raspberry Pi.

- Collects sensor data, processes it, and communicates with the cloud or mobile app.

CLOUD SERVER / MOBILE APPLICATION

- Stores real-time sensor data.

- Provides farmers with insights and remote control options.

- Can use platforms like Thing Speak, Blynk, or custom apps.
Irrigation System (Pump / Valves)

- Electrically controlled devices (solenoid valves, water pumps).

- Activated automatically by the controller based on soil an

TYPES OF SENSORS USED IN SMART IRRIGATION

1. SOIL MOISTURE SENSORS

These sensors measure how much water is available in the soil. When the soil becomes dry, they trigger irrigation, ensuring water is used only when necessary.

2. TEMPERATURE SENSORS

They record the surrounding air temperature, which helps estimate crop water needs. For example, crops need more water on hot summer days compared to cooler days.

3. HUMIDITY SENSORS

By checking the moisture in the air, these sensors help predict evaporation rates. High humidity means slower evaporation, and hence, reduced water requirements.

4. RAIN SENSORS

These detect rainfall. If it rains, the system avoids unnecessary irrigation, saving water and electricity.

5. WEATHER SENSORS

They provide real-time data about climatic conditions such as wind, temperature, and rainfall patterns. This allows predictive scheduling, where irrigation is planned ahead of time.

SCOPE IN KERALA AGRICULTURE

Kerala's unique geography, high rainfall variability, and crop diversity make it an ideal region for IoT-based smart irrigation. Traditionally, farmers here rely heavily on monsoons. But with changing climate, water

supply has become unreliable. Smart irrigation can bridge this gap by ensuring precise water delivery. Its applications include:

PADDY FIELDS

Controlled irrigation prevents both drought stress and excess waterlogging, leading to better yields.

BANANA AND COCONUT PLANTATIONS

These crops require consistent moisture levels. Smart irrigation can maintain ideal conditions, especially during dry spells.

SPICE CULTIVATION (PEPPER, CARDAMOM, GINGER)

Kerala is famous for spices, which are highly sensitive to water stress. Using IoT, farmers can improve both the quality and quantity of produce.

VEGETABLE FARMING

In polyhouses and open fields, precision irrigation ensures water efficiency and healthier crops.

By adopting these systems, Kerala's farmers can achieve sustainable farming, reduce their dependence on unpredictable rains, and cut down on electricity and water bills. It also empowers young, tech-savvy farmers who are keen to blend tradition with modern innovation.

ADVANTAGES OF SMART IRRIGATION

Smart irrigation systems bring multiple advantages to modern agriculture by combining technology with sustainable practices. One of the greatest benefits is efficient water management, as these systems apply water only when and where it is needed, based on real-time soil moisture, crop type, and weather forecasts. This reduces unnecessary water consumption and helps farmers cope with water scarcity, a growing concern in regions like Kerala. By maintaining optimum soil moisture levels,

For Kerala's agriculture, where smallholder farmers often face challenges of unpredictable rainfall and depleting groundwater, adopting smart irrigation can ensure resilient farming practices. It enables precise control over crop inputs, supports multi-cropping systems, and makes farming more adaptable to climate variability. Thus, smart irrigation not only improves productivity but also secures the livelihoods of farming communities in a sustainable way.

CONCLUSION

IoT-based smart irrigation is not just a technological upgrade; it is a farmer-friendly solution that balances tradition with innovation. For Kerala, where agriculture is facing new challenges every year, adopting such systems can revolutionize farming. By combining the wisdom of farmers with the precision of technology, we can build a future where every drop of water counts, and farming remains both sustainable and profitable.

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Chatbots & Conversational Agriculture

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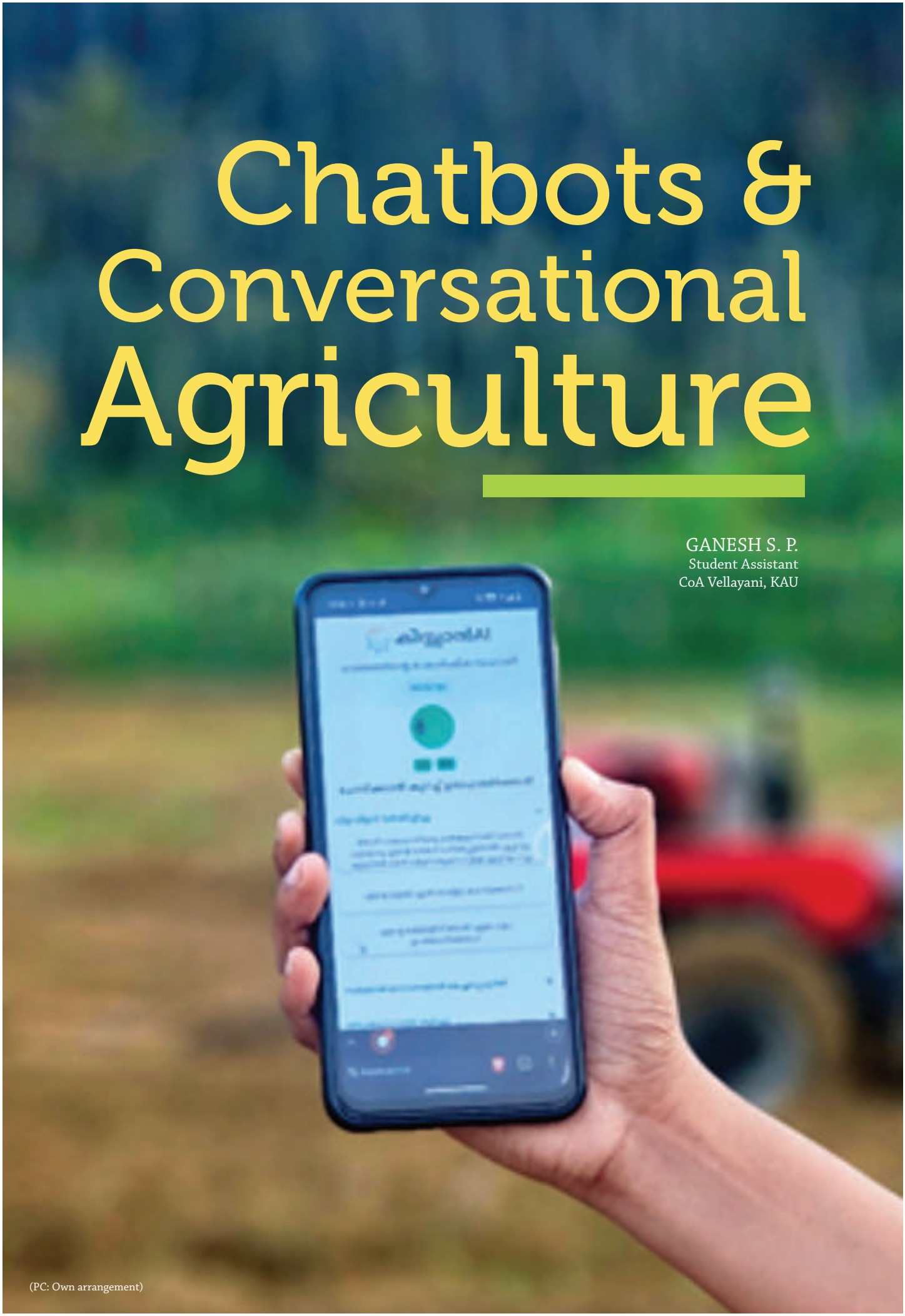

(PC: Own arrangement)

India's first fully digitally literate state, Kerala, is witnessing a quiet revolution in its farming practices. Farmers who once relied solely on traditional knowledge and seasonal patterns are turning their heads to their smartphones for real-time agricultural guidance. This transformation conveys that the growing farming community is hungry for adopting new-age technology to improve their farm productivity. The increasing number of techie-turned farmers has accelerated the technological innovations in the field of agriculture, which has turned into a boon for the state.

Usually, the farmers depend on the extension personnel and officers of Krishi Bhavan. In the era of agentic AI and chatbots, the farmers could get an extra hand or two in supporting their decisions related to managing the farm resources. Digital interventions in the field of farming are not a novel strategy in the state. The first such initiative dates back to 2019, when the Agriculture Information Management System (AIMS) was launched with over 41 lakh farmers registered across 30,000 farmer groups and Krishi bhavans. This overwhelming response revealed the huge appetite for digital agricultural services. Interactive, conversational support was still lacking, which set the stage for the next round of innovation: agri-chatbots and conversational agriculture. Conversational agriculture can be explained as accessing agri-advisory information via text/voice in a one-on-one conversation front-end interface powered by trained neural network in the back-end. Real-time personalised agricultural advisory services are the unique selling point for such conversational chatbots.

'Kisan e-Mitra' is one of the commonly used voice/text-based conversational bots to support the farmers on queries related to general schemes like PM-KISSAN, PM Fazal Bima Yojana, etc. It supports more than 11 regional languages, including Malayalam. However, it lacks the functionality to deliver more farm decision queries, which, by passage of time, could be trained for. With initiatives such as the 'National Pest Surveillance System,' we may have a solid repository to train the AI models for the crop advisory.

The private players like TATA Rallis have introduced WhatsApp-based chatbot made available 24x7 with quick access to crop advisory, expert guidance, and product information. AgWise, a leading smart farming solution service team, has blended agronomy and IoT based technology (through which you can experience conversational model with site specific alerts on irrigation parameters) is made available to the fingertips of farmers. 'Kissan AI' is another example which has penetrated a large number of farmers with their decent regional language support and voice-based copilot for crop advisory. Few custom chatbots are released from Statoberry LLP, a startup from Kerala Agricultural University that uses image-based training, based on Convolutional Neural Network (CNN) to identify the symptoms and provide recommendations against the diseases in pepper and cashew and is planning to upscale to more crops and varieties.

The Kerala Agriculture Technology Hub & Information Repository (KATHIR) is a hit among the farmers for accessing location-specific and crop-specific advisory. The penetration analysis reveals varying adoption rates from PM Kisan beneficiaries (28 lakh farmers), with a daily addition of around 15000-20000 registrations. The application helps provide comprehensive agri-related services like AI-based demarcation of farm fields, soil-testing requests, plant doctor consultations, crop and soil health monitoring, weather updates, along with relevant information about carbon neutrality and carbon credit markets.

Various decision-supporting tools are designed under Digital Agriculture Mission. Krishi Decision Support System (DSS) integrates remote sensing for drought/flood monitoring, geospatial data and weather/satellite data, modelling for crop yield and insurance, groundwater/water availability data, etc. Proper verification of identity and ownership of holdings of farmers by 'AgriStack- Kisan Ki Pehchaan' helps in the efficient and transparent transfer of government scheme benefits.

The farmers who are leading this quiet revolution of conversational agriculture to stay updated about their crop in relation to climate change will surely motivate more developers and government to deliver more. We might say that the support that farmers are getting from chatbots is unmatched with that of consulting extension personnel, yet technology is in its nascent stage, which makes us skeptical about the generative results. The digital literacy greatly impacts app navigation; integrating bots into applications like WhatsApp improves the adoption due to familiar interfaces. However, multilingual support in various chatbots may not be on the same page with the vernacular farm/market terms that the farmers often use. Language barriers can be tackled in future projects by potential collaborations with BHASHINI, India's own AI powered language translation platform under National Language Translation Mission. In the case of Kerala, over 55 lakhs farmers are undertaking cultivation across diverse agro-ecological zones from coastal plains to highland plantations therefore the accuracy of these chatbots should still be ensured and validated. Enough adoption workshops are to be conducted for the responsible and righteous use of the technology with the layman.

The quiet revolution has brought public and private institutions and startups to research and train more LLMs to improve the experience. Success stories are sure to emerge and reach new heights by integrating the agronomic practices with the relevant technology. We can expect integration of AI models with virtual reality for mapping real-world scenarios in a more immersive perspective, helpful for farmers, students, and researchers alike. The message is clearly stated as the future of agriculture, be it tuber cultivation in Thiruvananthapuram, cultivating spices in Wayanad, or growing rice in Kuttanad, conversational agriculture with smart farming solutions. With decision support tools make a difference in sustainable and profitable agriculture.

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DEADLY BEAUTIES IN **MUSHROOM** WORLD

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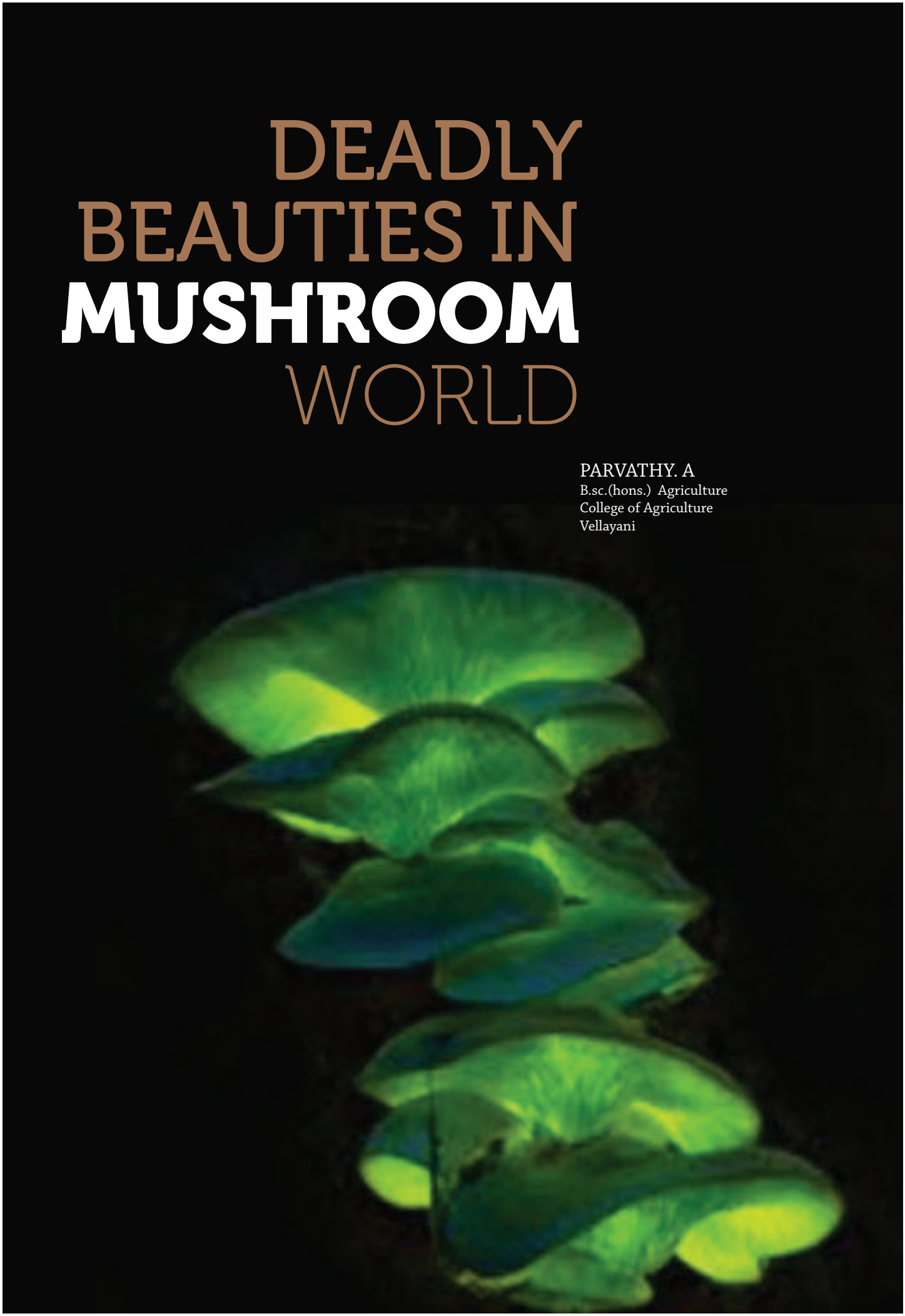


Fly Agaric


Fool's Conecapa


Ghost Fungi

There are currently about 140000 mushroom species known to exist worldwide. Among which, about 600 species are known with the presence of toxic secondary metabolites which can cause various health issues in human beings. So there lies the importance of proper identification of these poisonous mushrooms as misidentification is one of the major reasons for mushroom poisoning. These toxins may cause gastrointestinal disease, allergies, some psychedelic and some may even be fatal. Thus, correctly identifying a poisonous mushroom can prevent accidental consumption which can even lead to death, helps in safe foraging and also protects biodiversity.

Many of these poisonous mushrooms are brightly coloured and are attractive. Several morphological and physiological characteristics help in differentiating these deadly beauties from edible ones. Usually, poisonous mushrooms have an annulus, which is actually a ring-like structure around the stem, and a volva, a sac-like structure at the base of the stem. They might even have the presence of latex and also possess warts or scales on the cap. These toxic mushrooms can also become green or purple when cut.

Numerous historical accounts document instances of mushroom poisoning. German Emperor Charles VI was fatally poisoned by Amanita phalloides, a poisonous mushroom. Russian history says that Tsar Alexis and his wife (parents of Peter the Great) ate Amanita phalloides and died on January 25, 1694. In a similar vein, several instances of mushroom poisoning have been known since ancient times.

SOME POISONOUS MUSHROOMS

A mushroom known as death cap (Amanita phalloides) is responsible for 50 percent of cases of toadstool poisoning. It belongs to the genus Amanita, which is responsible for approximately 95% of the fatalities resulting from mushroom intoxication. The toxin present in these mushrooms is amatoxin, and as little as 30 grams (one cap) is enough to kill an adult. Several other mushrooms which contain amatoxin are destroying Angel (Amanita virosa), fool's conecap (Conocybe filaris), autumn skullcap (Galerina mariginata) etc. Muscimol and ibotenic acid are two toxins found in certain species of the genus Amanita. These include Panther Cap (Amanita pantherina), Fly Agaric (Amanita muscaria) etc.

Mushrooms belonging to Genus Psilocybe are psychotropically toxic, causing hallucinations and are illegal in many regions. Psilocybin and Psilocin are the toxins found in these types of mushrooms. Consuming these types of mushrooms might result in both psychological and physical side effects. Certain mushrooms under this category include golden cap (Psilocybe cubensis), liberty cap (Psilocybe semilanceata) etc. In addition to these, there are a number of additional toxic mushrooms, such as false morels (Gyromitra esculenta), which are named because they look like real morels. The toxin found in this group of mushrooms is Gyromitrin and causes neurological and hepatic damage.

Clitocybe and Inocybe mushrooms can cause muscarinic poisoning due to the presence of the toxin muscarine. A mushroom named Coprinus atramentarius (Ink cap)can cause a unique poisoning called Coprinus syndrome when alcohol is ingested up to 2–3 days after eating the mushroom. The toxin involved is Coprine. Fool's


Autumn Skullcap


Coprinus


Golden Cap


Liberty Cap


Panther Cap

Web (cap Cortinarius orellanus), Deadly Webcap (Cortinarius rubellus) , Ghost Fungus(Omphalotus nidiformis), Agaricus californicus, Tiger Tricholoma (Tricholoma pardinum), Man-on-Horseback (Tricholoma equestre) are examples of some other poisonous mushrooms.

SYMPTOMS

If we consume a poisonous mushroom, we may not feel any symptoms right away. It can take hours or even days for the toxins to take effect. The symptoms of mushroom poisoning can vary depending on the type of mushroom and the individual's sensitivity. The common symptoms include gastrointestinal issues like nausea and vomiting, abdominal cramps and pain, diarrhoea or bloody stools. Other symptoms ar allergic reactions, headaches or migraines, dizziness, confusion or disorientation, respiratory problems, rapid heartbeat or palpitations, low blood pressure or shock, kidney or liver damage — etc. Severe cases can lead to seizures or coma and even death.

MANAGEMENT

Proper treatment should be taken when poisonous mushrooms are ingested. The first and foremost thing that we should do in case of mushroom intoxication is to stay calm and seek medical help. If possible, bring a sample of the mushroom to the hospital or photos from multiple angles. Treatment methods include fluid replacement techniques, electrolyte management methods, etc. to prevent dehydration and correct electrolyte balance. Gastrointestinal decontamination using activated Charcoal (within 1–2 hours of ingestion) or gastric lavage can be done. In severe cases, hospitalization, hemodialysis etc. are preferred. Specific treatment methods include the use of antidodes like Silibinin and penicillin G for amatoxin poisoning, Atropine(Muscarine poisoning), Pyridoxine (Vitamin B6) for gyromitrin poisoning, and antipsychotics (Psilocybe poisoning), are available.

STATISTICS AND RECENT CASES

Every year, more than 10,000 cases of mushroom poisoning are reported. Approximately 100–200 deaths occur worldwide each year. The main reasons for this are confusion between edible and toxic species, traditional wild mushroom foraging and misidentification. About 30% of accidental ingestion involve children in the age group of 0–12, and they are the most vulnerable due to curiosity. Reports of occasional deliberate consumption of Psilocybe sp for hallucinogenic effects among adolescents (13–18 yrs) is common these days. In Asia, the high risk regions include China, India, Nepal and Bhutan. In India, several cases were reported in the year 2024-25. These include a major incident in Saphai village (Meghalaya) that led to 3 minors' deaths and several others critically ill in 2024. Another one is in the East Jaintia Hills of Meghalaya, where 15 cases were reported, resulting in 6 deaths between April and early May 2025.

Particularly in areas where foraging is prevalent and deadly species are frequently confused for edible ones, mushroom poisoning continues to pose a serious health danger. Some cases, particularly those involving amatoxins, might result in serious liver or renal failure and death, while many merely cause moderate gastrointestinal symptoms. Reducing morbidity and death from mushroom poisoning requires early detection, timely medical attention, and raised public awareness..


Death Cap


Destroying Angel


False Morels

Acid Lime: India's Tangy Treasure with Growing Potential

INTRODUCTION

Acid lime (Citrus aurantifolia Swingle) is one of the most important fruits in India. It is considered to be indigenous to India and is extensively cultivated in many states under tropical and subtropical climatic conditions. India is the largest producer of acid lime in the world. Due to its lower production costs relative to mandarins and sweet oranges, combined with superior shelf life and high market demand, the area under acid lime cultivation is steadily expanding each year. As of 2023-24, acid lime was cultivated on approximately 0.32 million hectares, yielding 3.83 million metric tons with a productivity of 12.02 t/ha (MoAFW, 2025). In Kerala, where land availability for fruit growing is limited, acid lime cultivation is gaining popularity in recent times for field growing and more importantly for container farming, which is particularly relevant in the context of Urban Horticulture.

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NUTRITIONAL COMPOSITION

Nutritional value per 100 g

Energy	126 KJ (30kcal)
Carbohydrates	10.5 g
Sugars	1.7 g
Dietary fibre	2.8 g
Fat	0.2 g
Protein	0.7 g
Water	88.3 g
Vitamin C	29.1 mg

HEALTH BENEFITS

The acid lime fruit is an excellent source of vitamin C, which aids in boosting one's resistance to numerous diseases, and it is known for its antidiabetic, anticancer, antibacterial, anti-inflammation, antifungal, anti-lipidaemia, anti-hypertensive and antioxidant properties. The oranges, lemons and limes are also high in limonoids, a group of phytochemicals (Manjusha et al., 2023). It has been discovered that its antioxidant properties are highly powerful against cancer.

SEASONS IN ACIDLIME CULTIVATION

There are three important seasons in acid lime cultivation Ambia bahar (January-February), Mrig bahar (June-July) and Hasta bahar (September-October). Among these three bahars, the crop bearing flowers during the month of September October is the best because it comes to harvest during summer which indeed helps in procuring high lucrative price. In order to get the maximum returns from summer season, the plants are treated with growth regulators and chemicals to promote production in order to reap the greatest benefits, i.e., foliar spraying with GA_3 50 ppm + Cycocel 1000 ppm is done for extending the harvesting period (Lakshmi et al., 2014).

VARIETIES

PUSA UDIT:

Released by IARI, medium sized fruits (40.0 g), round to ovoid shape, smoot fruit surface, thinner peel, high juice content (48.51%), ascorbic acid (48.60 mg per 100 ml juice) and acidity (7.40%). Tolerant to canker.

PUSA ABHINAV:

Pusa Abhinav is a promising clonal selection having medium vigorous trees, dense foliage and attractive yellow round shaped fruits. It has round the year fruiting with peak harvesting during March-April and August-September. Moderately susceptible to citrus canker. It has medium sized fruits (38-40 g) with high juice content (57.0%) and acidity (7.7%). Average yield 20t/ha.

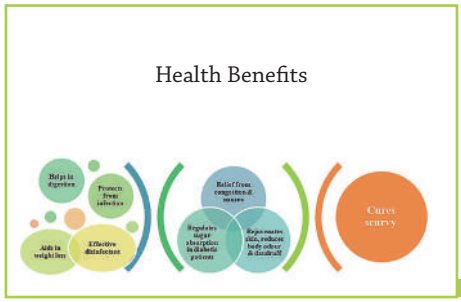
NRCC ACIDLIME-7: Released by NRCC, Nagpur. Fruits single; juice 50.5%, fruit weight 48g; yield 4069 fruits/tree; 54t/ha

NRCC ACIDLIME-8: Released by NRCC, Nagpur. Fruits in bunches; juice 51.5%, fruit weight 50g; yield 4237 fruits/tree; 59t/ha.

PDKV LIME: Evolved through selection from local lime. Seeds/

FRUIT:
9 to 10, juice content is 54%;
peel thickness 1.5-2.0mm; TSS 10.92; Acidity 6.58%. Yield 18-20 kg/tree (35% higher yield over Vikram), best marketable quality due to round shape.

PDKV BAHAR:
Cluster bearing, peel thickness 1.62mm, 53% juice and ascorbic acid content 31.47mg, yield 34.5t/ha; minimum incidence of canker.



PDKV CHAKRADHAR:
Released by Dr. PDKV, Akola. Seedless & thornless, cluster bearing. Fruits have attractive colour and medium in size. Peel thickness 1.02mm, acidity 5.9%. High in Vitamin C (30.3mg), high juice 60-65%, yield 18 20t/ha.

PDKV TRUPTI:
The fruit is round to oblong, yellow at maturity. Fruits are large weighing 59-60g, with average 53.50g wt. of ambia bahar fruits. Seeds: 9-10 and highly polyembryonic. Yield: 25-27 tonnes/ha.

BALAJI:
This cultivar is a selection from Tenali and was released by CRS, Tirupati (Andhra Pradesh). Fruit is medium in size, attractive in appearance and juicy. Resistant to canker, moderately resistant to dry root rot. Immune to bark eruptions. Recommended for AP & Telangana.

PETLUR SELECTION 1:
Clonal selection developed by CRS, Petlur (Andhra Pradesh). Tree with spheroid shape. High branching density. High yielder with cluster bearing habit. Fruits spheroid in shape with smooth and thin rind, fruit apex truncate. Fruit has about 10 segments and 8 seeds. High juice content (55.8%) with high citric acid (7.3mg/100g). Fruit yield: 210 - 220 kg/tree /year. It has the ability to yield more during summer season. Resistant to bacterial canker disease, immune to bark eruptions and moderately resistant to dry root rot disease.

VAKULA:
Developed through clonal selection by CRS, Tirupati. Suitable for high density planting. High yielder with cluster bearing habit and flowers round the year. Fruits are big (45 g) oval in shape with smooth, shiny and thick rind (3 mm). High juice content (45 %). Yield: 20.0 – 39.0 t/ha. More suitable for pickle and salad industry. Tolerant to bacterial canker disease (6%).
SAI SHARBATI: This excellent selection was made by MPKV, Rahuri. Fruits are roundish smooth with thin rind, 7.93% TSS and 54.41% juice content. This is usually tolerant to canker and phytophthora with average yield of 1,200 fruits/tree/year

PHULE SHARBATI:
Released by MPKV, Rahuri. Yield: 45-50t/ha, high summer cropping (25.42%); high juice content 52.5%.

PKM-1: Released by TNAU. Tree is vigorous. This can be easily multiplied as seedlings and layers. Fruits can be harvested throughout the year. Big fruits (52g), high ascorbic acid (34.29mg/100 fruit juice); juicy (52%), pleasant aroma. It is a high yielder. The average yield per tree/year is 934 fruits weighing 36.975 kg. it is less susceptible to leaf miner & citrus butterfly.

SNKL 1:
Clonal selection from SNKL 19. Year around production with cluster bearing habit (5 fruits/cluster). More peel thickness (1.95 mm); Suitable for long distance transport and more shelf life (10 days). High juice content (54.1 %). Average yield: 58.20 kg/tree/year (16.60 t/ha). Moderately resistant to leaf miner, citrus butterfly, mites, gummosis, canker and dieback.

JAI DEVI:
This cultivar has been mostly adapted in Tamil Nadu, Andhra Pradesh and Karnataka. This is a selection from ecotype of 'Kadayam' tract of Tirunelveli district of Tamil Nadu. It has high yield potential of 1,500 fruits/tree (50kg/ year). The juice content is high (52.3%) and tolerant to pests like leaf miner and citrus butterfly.

RASRAJ:
It is canker resistant hybrid variety developed at IIHR, Bengaluru. It is cross between Kagzi nimboo x Nepali Gol Lemon. Fruit weighs 50g with juice 45%, acidity 6.8%.

VIKRAM:
This cultivar was developed by MAU, Parbhani. Off-season (2 crops/year) & cluster bearing (5-10 fruits/cluster); fruit weight 46g. This is a high yielder (32.6 tonnes/ha).

PRAMALINI:
The cultivar was developed by MAU, Parbhani. Cluster bearing (3-7), fruit wt. 46g; high juice (57.72%); off-season bearer and high yielder (34.5 tonnes/ ha). Trees are canker & phytophthora tolerant.

PROPAGATION

Acid lime trees are propagated both by seeds and vegetative means. Seed propagation is still practiced in the case of acid limes due to nucellar origin of seedlings, since it ensures true-to-type plants with uniform quality and regular bearing. Shield or T budding is the most commonly used method of vegetative propagation. Budding is generally done either in spring or in September.

CONTAINER FARMING

Container farming is a micro model of farming where a household is producing fruits and vegetables in special containers.
Different kinds of containers are used commercially such as used tyres, clay pots, bamboo baskets, plastic buckets and plastic bags of different sizes (Issarakraisilaa, 2018) Limes are successfully grown in 45x60 or 45x45 cm sized containers for getting good fruit quality. In primary nursery, seedling emergence and survival was maximum in Potting mixture (PM) + cocopeat (CP) (40+20+20 in PM + CP media) (Marathe et al., 2020). Nowadays, growing lime in containers is widely spread as it provides a model for the control of flowering time and canopy size under tropical conditions. HDP (3x2.5-5x5m) and UHDP (2.5x2.5m) are also followed for acid lime.

SCOPE OF ACID LIME CULTIVATION

Acid lime cultivation in India has a promising future due to its wide adaptability, consistent market demand, and profitability. With increasing awareness, support from government schemes, and growing demand in both domestic and international markets, acid lime has emerged as a suitable crop for improving farmer income and promoting sustainable horticulture in the country. Container grown acid lime can be included as a promising component in urban horticulture. Standardisation of nutrient management, pruning and crop regulation in container growing of acid lime is the need of the hour.

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Nicobari macaranga leaves can replace **disposable food plates!**

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Fig: clock-wise: Macaranga nicobarica – under natural conditions in Champin Islands, Nicobar; Field establishment of saplings at RS Thrissur; Individual leaf

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Extensive and unscrupulous use of non-biodegradable polythene has become a severe public menace spoiling water bodies, tourist spots and other public spaces. It is high time that we act locally to combat this menace. The commonly accepted three R's, reduce, recycle and reuse needs to be implemented in right earnest by every individual for the common benefit of mankind and to save this planet for future generations. It is in this context that we have to think about reviving our traditional eco friendly practices of our ancestors especially for packing and wrapping food items.

Wrapping meals in a flaccid green banana leaf was a common food packaging practice in Kerala and it is still practiced to a great extent in the rural households. In order to improve shortage of green banana leaves, the Education Department in collaboration with Agriculture Department may promote planting a banana sucker per homestead by each student. Barring a few apartment dwellers majority of the students can adopt a banana plant. Being a fast growing herb with plenty of suckers, it will help to reduce the use of polythene wrappers for packed lunch. Wrapping hot meals in green banana leaves is believed to have positive health benefits by way of the cooked meals imbibing some of the essential nutrients and vitamins from the banana leaf. The ubiquitously distributed and delicious 'Njalipoovan' banana variety will be ideal as it produces plenty of suckers, besides the leaf size being ideal for packing meals.

Further, ecofriendly use of local flora for food wrapping and packing needs to be promoted. Leaves of 'Vatta' (Macaranga peltata) Teak, Turmeric and 'Murikku' (Erynthrina indica) were used extensively as food plates or wrappers for cooking food and or serving food during public gatherings and feasts. A related species of 'Vatta' namely Macaranga nicobarica, occurring in the wild state in Nicobar forests, but having much bigger leaf size of our 'Vatta' may be a good candidate for promoting as an alternative to plastic food plates. It has a leaf size of 70 x 60 cm, good enough the size of an extra-large serving plate. It is highly adapted to the ecological conditions prevailing in Kerala and a few seedlings flourish at the ICAR-NBPGR Regional Station, Thrissur and ICAR-CIARI campus, Port Blair, Andaman and Nicobar Islands. Propagation is through seeds and seedlings grow very fast. The broad leaves being an intact single piece, unlike the North Indian stitched sal leaf plates does not leak and hence will have an edge over stitched leaf plates. Nicobari tribes use its leaf for wrapping pandanus cakes before steaming. The traditional eco friendly practice of using leaves of taro, vatta, Erythrina (for idli cooking), teak, etc. needs to be revived and machines for devising plates out of these leaves and Areca sheaths, needs to be worked out. Intact palm leaves like Corypha umbraculifera (kudappana) and its dwarf cousins can also be worked out as plates by machine cuttings. Research agencies and 'Kudumbasree' units may make joint effort to utilize the wisdom of indigenous people for eco friendly and green Kerala.

NEXT-GEN HYDRATION: EXPLORING THECUTTING-EDGE TRENDS IN BEVERAGE INNOVATION

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The beverage market is evolving rapidly and there has been a noticeable trend toward hydration options that do more than just quench thirst. Hydration is more than just drinking water in today's wellness-conscious society; it also includes functional beverages that offer convenience, taste, and additional health advantages. Innovation, convenience, and personalization are key components of "next-gen" hydration, which includes everything from smart bottles to nutrient-rich beverages. Present-day consumers prefer beverages which include electrolytes for hydration, protein, or minerals like curcumin, B vitamins, or prebiotics. Over the coming years, the global market for hydration beverages is predicted to grow significantly. Plant-based beverages, electrolyte-enhanced waters, and smart hydration solutions are expected to increase in popularity as consumers turn to functional hydration and wellness-focused drinks. In 2023, the global market for functional beverages was valued at around $154.44 billion, having expanded at a compound annual growth rate (CAGR) of 5.5% since 2008. The market is anticipated to expand at a 5.8% annual pace from $154.44 billion in 2023 to $204.74 billion in 2028. In 2033, the market is anticipated to have grown to $277.89 billion at a compound annual growth rate (CAGR) of 6.30% from 2028 (Research and Market, 2024). Similarly, the global market for electrolyte drinks alone is predicted to increase from $35.20 billion in 2023 to over $58 billion by 2032, according to industry research. The India Functional Beverages Market, broken down by type, is anticipated to grow at a remarkable CAGR of about 9.18% from 2020 to 2025, reaching a value of about $2.20 billion. The market for next-gen hydration is anticipated to grow significantly over the next several years as consumers' preference for non-alcoholic and health-promoting beverages grows. Especially, the functional beverages industry is predicted to increase significantly in the next years due to rising health consciousness among various consumer groups and rising spending on wellness and health products. The market-trend-based strategies for the functional beverages market include new developments in the relaxation beverage industry, creating protein-based functional drinks, developing AI-driven functional drinks, developing vegan and plant-based functional beverages, launching nootropic drinks to improve focus and brain health, and forming strategic alliances and partnerships among market participants.Next-generation hydration products use cutting-edge ingredients and formulations that boost fluid intake and promote general health. Here are a few examples of important categories of next-gene hydrations,

1.HYDROGEN-RICH WATERORHYDROGENATED WATER:

In the field of health and wellness, hydrogen-rich water has become an innovative approach. It is said to contain antioxidant qualities that may neutralize the body's damaging free radicals. Because of its anti-inflammatory and anti-apoptotic properties, it has also been demonstrated to be helpful in reducing damage caused through oxidative stress.

2.PROTEIN-BASED FUNCTIONAL DRINKS:

Protein-based functional drinks are made to offer an easy source of protein and are often mixed with other functional ingredients to promote health advantages. These beverages serve those who want to increase their protein intake for several reasons, such as improving their general health, managing their weight, or recovering from injuries.

3.NUTRACEUTICAL DRINKS:

Non-alcoholic beverages designed to offer health advantages beyond simple nourishment are known as nutraceutical drinks. With the goal of promoting general well-being and preventing chronic diseases, they include functional elements such vitamins, minerals, probiotics, dietary fibers, amino acids, and herbal extracts.

4.DAIRY-BASED FUNCTIONAL BEVERAGES:

Dairy-based functional beverages are non-alcoholic drinks that combine traditional dairy products with added functional ingredients to enhance health benefits. These beverages aim to support various aspects of health, including digestion, immunity, and overall well-being.

5.ELECTROLYTE DRINKS:

Electrolyte drinks are developed to replace vital minerals that are lost through perspiration during physical exertion, illness, or dehydration. These minerals include sodium, potassium, calcium, and magnesium. These minerals are essential for nerve transmission, muscular contractions, and fluid homeostasis.

6.ENERGY DRINKS:

Energy drinks are non-alcoholic beverages designed to improve physical and mental performance. In addition to additional substances like vitamins, amino acids, and herbal extracts, they usually contain large amounts of sugar and caffeine. These beverages are advertised as boosting stamina, energy, and focus.

7.SPORTS DRINKS:

Sports drinks have been developed to help athletes and other active people in replacing electrolytes and rehydrating

after engaging in physical exercise. Water, sugars, and electrolytes including calcium, magnesium, potassium, and sodium are usually found in them.

8.ENHANCED FRUIT DRINKS:

Enhanced fruit drinks are mixtures made from traditional fruit juices and other substances intended to offer additional health benefits. Natural sweeteners, vitamins, minerals, electrolytes, and herbs are a few examples of these enhancements.

9.HYDRATION POWDERS AND DRINK MIXES:

Drink mixes and hydration powders are powdered supplements that are made to be combined with water to enhance its flavor and add essential nutrients that help with hydration and overall wellness. These products are particularly popular among athletes, fitness fanatics, and people who want to increase their daily fluid intake.

10.NOOTROPIC DRINKS:

Drinks that contain cognitive enhancers provide consumers mental ability sufficient to satisfy the demands of contemporary life. The US biotechnology business Kyowa Hakko USA introduced CENTR Enhanced Functional Sparkling Water with Cognizin Citicoline in February 2023. This low-calorie, non-GMO, gluten-free, and vegan beverage, which comes in two flavors—lemon lime and peach ginger—is made to improve mood and cognitive performance. It's a delightful and health-c

onscious choice for anyone looking to boost their mental energy. Nootropic drinks enhance mental clarity and focus.

11.RELAXATION BEVERAGES:

Relaxation beverages are non-alcoholic drinks formulated to help reduce stress, promote relaxation, and improve sleep quality. Unlike energy drinks that aim to boost alertness, these beverages focus on calming the body and mind.

12.AI-DRIVEN FUNCTIONAL DRINKS:

AI-driven functional drinks are beverages developed with the assistance of artificial intelligence (AI) to enhance their health benefits and optimize their formulations. By analyzing vast amounts of data, AI can identify consumer preferences, predict trends, and suggest ingredient combinations that improve the drink's functionality and appeal.

Next-gen hydration drinks available in the international market

A low-caloric range of flavored and functional drink

Functional coffee

Functional sparkling water infused with cognizin citicoline

Magnesium infused relaxation drink

AI-powered zero caloric cola

Next-gen hydration drinks available in India

Nutraceuticals rich drink

Relaxation Beverages

Sparkling protein water

Electrolytes drinks

Hydration drink

The demand for the above-mentioned drinks produced with natural, plant-based components is rising. Customers who are concerned about their health will find these trends interesting, and they also promote environmental sustainability. In general, next-gen hydration are utilizes natural fruits and other natural ingredients, which are becoming more and more popular due to their flavor and health advantages. Numerous next-generation hydration drinks are made to promote exercise by improving performance, assisting in recovery, and resupplying electrolytes. Moreover, these drinks frequently have unique and exotic flavors to increase customer engagement while offering a more pleasurable and sensory-rich hydration experience. Most convenient forms of next-generation hydration drinks include single-serve pouches, portable powders, and ready-to-drink bottles. With these options support hectic schedules, customers can stay hydrated and reap the health advantages all day long.

In addition, with the previously listed next-generation hydration trends, innovations like smart hydration monitoring, sustainable hydration packaging, smart water bottles that track water intake and send reminders to smartphone, hydration apps and digital tools, hydrotrack wearable hydration monitor, etc., represent a larger trend towards customized sustainable, and health-oriented hydration solutions that meet the varied preferences and lifestyles of today's consumers.

EVALUATING NEXT-GENERATION HYDRATION TRENDS: BENEFITS AND DRAWBACKS

Trends in next-generation hydration are changing the way we think about fluid intake by highlighting practical benefits as well as customized solutions. The following highlights the advantages and disadvantages of these freshly emerged trends:

ADVANTAGES

1.ENHANCED FUNCTIONAL BENEFITS:

In order to promote general wellness, energy levels, and cognitive function, modern hydration products often incorporate vitamins, adaptogens, and electrolytes.

2.TARGETED HEALTH SUPPORT:

Besides basic hydration, some beverages have been developed to meet particular health requirements, like gut health, brain function, and immune support.

3.CONVENIENT REHYDRATION:

Powders and ready-to-drink (RTD) alternatives offer quick and easy hydration options, making them ideal for people who lead busy lives or are constantly on the go.

4.REACH A BROAD SPECTRUM OF POPULATIONS:

Marketing strategies are increasingly focusing on non-athletes and women, widening the market for hydration commodities.

DISADVANTAGES

1.POTENTIAL OVERCONSUMPTION OF ELECTROLYTES:

Even while electrolytes are necessary, consuming too much of them can cause problems like hypertension. Electrolyte intake should be balanced with personal requirements and activity levels.

2.ADDED SUGARS AND ARTIFICIAL INGREDIENTS:

Sometimes hydration options may incorporate a lot of artificial ingredients or additional sweets, which might counteract their health benefits and cause other health issues.

3.COST CONSIDERATION:

Although premium hydration drinks with additional useful components can cost more than regular water, some customers may not be able to afford them.

4.LACK OF SCIENTIFIC KNOWLEDGE:

More extensive study is required to completely understand the safety and effectiveness of next-gen hydration trends like hydrogen-rich water, even though some studies have suggested potential benefits.

CONCLUSION

"Next-gen" hydration is about making drinks that are sustainable, practical, individualized, and useful, not merely about drinking more water. The future of hydration is bright, varied, and in accordance with the expanding health and wellness trend thanks to revolutionary developments in hydration powders, smart technologies, plant-based substitutes, and environmentally friendly packaging. The beverage business is clearly going to have a significant impact on how we lead healthier lives as we continue to find new ways to improve our hydration habits.

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GENE EDITING TECHNOLOGY TO **IMPROVE THE LIVELIHOOD OF CASSAVA FARMERS**

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India, despite is greater than world average productivity of cassava, is still importing starch to meet the requirement of modified starch as raw material by starch based industries. Starch based industries are of wide ranging starting from pharmaceutical industries, where starch is used as a filler or binder and frozen food industries, adhesieve making, papermaking, photographic film making to fururistic bio based industries producing bio-fuels and biofilms. In planta generation of modified starch can revolutionize the Indian starch market and bring huge value to the cassava crop and additional imcome to cassava farmers.

Altering the physiochemical properties of starch can bring out a better application to native starch and this is where the CRISPR/Cas based genome editing comes into play.

The starch biosynthesis pathway involves some common basic steps in all tuber crops. The enzymes involved in the starch biosynthesis pathway can be edited by regulating the expression of genes encoding these enzymes.

The amylose and amylopectin are two components of starch, the ratio of which determines the physiochemical properties of the starch. By nullifying the expression of gbss gene coding for gbss enzyme responsible for amylose synthesis, we can develop waxy starch with no amylose content. Such starch has use in frozen food industry and adhesive making industry in addition to textile and corrugated paper industry and photographic film making among many other applications.

High amylose starch is good for gut. It is called resistant starch and not absorbed in the intestine resulting in fermentation and by products that feed the gut bacteria and improves colon health. This type of starch can be considered futuristic as it is a hope for diabetic persons who craves for tuber crops in their diet. High amylose cassava can be also looked forward as source of biofuels and bio degradable plastic. To develop high amylose starch, the amylopectin content can be reduced. It is also done by regulating the expression of starch branching enzyme coding genes. Previous studies has reported the silencing of SBEII as a means to reduce the amylopectin and thereby develop high amylose starch in cassava.

The pre requisites for CRISPR Cas9 based genome editing is the genome sequence of the crop and also an efficient transformation system. With trait associated gene/s identified, a modification of the gene expression can be attained through induced mutations (addition/deletion/ substitution of base) and the resulting repair altering the gene expression.

The crux of gene editing technology depends on the factor that DNA has the ability to repair itself subsequent to a double strand break. The site where the DNA breakage happens is precise and regulated and the type of DNA repair path way is also pre determined. The repair pathway is either Homology Directed Reapir HDR or non-homologous end-joining (NHEJ). The NHEJ involves a random repair where either addition or deletion or substitution happens in during the repair. It is much like a natural mutation, only the site of double strand breakage is designed as per requirement. This type of gene editing is particularly useful in case of loss of function mutations. If a repair is to be done in a homology dependent manner, a designed stretch of DNA is provided in the CRISPR construct based on which the repair happens through Homology Directed Repair (HDR).

NHEJ repair falls under SDN1 regulation. In this type of Gene editing a few bases of the DNA are deleted or added during the random repair taking place after a site directed cut, renedering the gene non functional. The mechanism of SDN1 type of genome editing is mostly a loss of function mutation in which the gene regulating a particular trait is losing its functionality, following a random repair of the DNA.

Initially, the guide RNA designed to target a particular gene identifies the PAM sequences and binds to the specific site of the gene. The Cas enzyme cleaves the DNA, leading to a random repair of the DNA. As the repair is random, it is errorprone and leads to loss or addition of bases or alterations in the bases, leading to a loss of functionality of the particular gene. This type of gene editing is highly similar to natural mutation, where consequent to an DNA breakage, the DNA repairs by itself.
The SDN2 type of DNA repair is more stringent, where the repair of DNA happens according to a reference strand provided (Homology Directed Repair). So it is more precise kind of editing where the type of DNA repair is regulated.

Govt. of India has permitted the development of novel varieties, through SDN1 and SDN2 technology, strictly following monitoring at different levels for the biosafety, from institute level to RCGB approval. SDN3 is regulated as in the same way as transgenic technology. The decision has opened new avenues for the agricultural scientists to explore. Improved varieties are in pipeline and these varieties can bring a major surge in farmers revenue.

The starch pathway genes can be regulated through loss of function mutations. For example a CRISPR based construct targeting gbss gene can induce a loss of function of gbss gene, resulting in impaired amylose synthesis, and finally waxy starch generation in planta. Similarly the silencing of SBE can resulti n reduction of amylopectin and thereby increase of amylose content.
Thus CRISPR cas9 mediated gene editing has big scope in development of modified futuristic based starch from cassava.

MINIATURE COWS- THE MINI MARVELS FOR SUSTAINABLE INDIAN DAIRYING

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ABSTRACT

India has basically been an agricultural country. Livestock rearing has been an integral part of the socio-economic framework since time immemorial and is a vital sector of agriculture. Miniature Indian cattle breeds such as Vechur, Kasaragod dwarf, Punganur, Nadipathy and Malnad gidda have small stature with high adaptability. They require less feed and produce milk of distinct compositional and functional value and have the ability to thrive in challenging environments. Their milk is reported to have better digestibility and resistant to diseases when compared to crossbreds and exotic breeds. These traits position them as practical options for small holders in peri-urban dairying contributing to food security, employment and income generation for local communities. Conservation, breed-specific value addition and farmer awareness are potential keys to unlock their socio-economic and ecological potential.

INTRODUCTION

Milk is often called a "complete food," packed with essential nutrients like calcium, protein, vitamins B2 and B12 and healthy fats. Fresh cow milk supports bone health, boosts immunity and provides lasting energy. It is a natural remedy for fatigue, digestive issues, and even sleeplessness (Pathak & Bhatnagar, 2018). Its rich, creamy taste is loved by all. There are over 800 breeds of cattle distributed all over the world. About 80 per cent of the total cattle population belongs to nondescript or desi type with varying production potentials. India is the largest milk producer in the world with an annual production of over 230 million tonnes (NDDB, 2024). The dairy industry in India faces certain challenges such as,

- Rise in the cost of feed concentrates and fodder scarcity
- Climate variability impacting animal health, fertility and productivity
- Land fragmentation limiting scope for large-scale dairy units
- Shift in consumer demand towards functional dairy products

In this changing landscape, the sustainability of high-input dairy system is a question, particularly for small scale farmers in India. Crossbred and exotic animals, though are high-yielders, are often more susceptible to heat stress, parasitic infestations and feed-related metabolic disorders when reared in resource-limited environments.

"Vechur cow — the world's smallest cattle breed, native to Kerala (Photo: Wikimedia Commons user Manjithkaini, CC BY-SA 3.0)"

MINIATURE INDIGENOUS CATTLE BREEDS

Indigenous dwarf breeds offer attractive option for farmers and consumers seeking healthy and sustainable locally produced products that aligns with eco-friendly organic farming practices. Vechur, Kasaragod dwarf, Punganur, Nadipathy and Malnad Gidda are few of the miniature cattle. They are defined by a height of less than 110 cm at the withers (NBAGR, 2021) and have evolved over centuries in specific agro-ecological niches with characteristics of high tolerance to tropical heat, innate resistance to local parasites and diseases and ability to thrive on low-quality forages. They are found to produce milk with distinctive compositional traits, including high fat and protein content and predominance of A2B-casein. Further research is warranted to investigate the short and long-term effects of consumption of A2 B-casein proteins. Studies on Vechur and Kasaragod dwarf cattle have revealed significant antioxidant activity and antimicrobial potential in their milk, opening opportunities for developing functional dairy products and their potential in micro-dairy models.

BREED PROFILES

Vechur

The Vechur, recognised by the FAO as one of the smallest cattle breeds globally (~87–90 cm height) is a hallmark of Kerala's indigenous livestock heritage. It stands out as a flagship model for miniature breed promotion, combining cultural value, conservation success and scientifically validated production traits. The breed was rescued from near extinction in the late 1980s through conservation programs at Kerala Agricultural University (Iype, S. 1996). Milk production is 2–3 L/day with a fat content of 4.5–5.5%. Jain et al., 2023 proved antibacterial activity against E. coli and Salmonella It shows documented resistance to tick infestation and strong heat tolerance, reducing veterinary and management costs (Devapriya et al., 2021). The milk had higher total solids than many crossbreds, suitable for premium products like ghee, probiotic yoghurt and traditional sweets.

KASARAGOD DWARF

The Kasaragod dwarf is the native of Northern Kerala that has 96–107 cm height is valued for its compact build, docile temperament and resilience in humid coastal climates. Average daily yield is modest (1.2–1.5 L), but the milk is rich in protein (up to 3.8%) and fat (4.0–4.5%) with a notable antioxidant activity than the vechur milk (Devapriya et al., 2021; Ramesh et al., 2022 and Jain et al., 2023).

PUNGANUR

Punganur cattle stands just 70–90 cm in height. They are well adapted to the drought-prone Chittoor district of Andhra Pradesh and has a yield of 3–5 L/day with exceptionally high fat (~8%), making them unique among miniature breeds. It is used for making superior ghee and khoa with enhanced sensory quality (NBAGR, 2021). This breed is found in very few number and is on the verge of extinction.

NADIPATHY NANO

Nadipathy or "nano" cattle are extremely small, often less than 60 cm and are maintained mainly in goshalas in Andra Pradesh. The yield is typically 0.5–1.0 L/day, hence adequate for household and local sales. The fat content is about 4.0–5.0% and has a protein-rich profile

MALNAD GIDDA (KARNATAKA)

Malnad Gidda, averaging 90 cm, is a hardy hill breed adapted to forest grazing and native of Karnataka. They thrive in free-range systems with diverse vegetation (Rao et al., 2018). Pasture-fed animals show higher omega-3 fatty acids and bioactive metabolites in milk (Ramya et al., 2020). Reports indicate low incidence of FMD and parasitic infestation in pure herds and browsing habit helps control undergrowth, fitting into integrated crop-livestock systems (Rao et al., 2018).

MILK QUALITY AND FUNCTIONAL PROPERTIES

Prevalence of A2 B-casein

Large-scale genotype screening confirms the prevalence of A2 B-casein in most indigenous Indian cattle, including miniature breeds. They carry the A2 genotype at the B-casein locus, with allele frequencies often above 0.95 (Singh et al., 2022). This milk is increasingly preferred by consumers due to better digestibility and lower association with gastrointestinal discomfort (Truswell, 2005). For breed conservation programs, maintaining this genetic trait is an added marketing advantage.

ANTIOXIDANT POTENTIAL

Jain et al. (2023) reported higher DPPH radical-scavenging activity in milks of Vechur and Kasaragod dwarf compared to crossbred Holstein-Friesian cows. The property is attributed to the occurance of greater levels of bioactive peptides and antioxidant vitamins. This opens pathways for functional dairy products targeted at health-conscious markets.

"Kasaragod Dwarf cow grazing at Neelamperoor, Kerala (Photo: Wikimedia Commons user Vijayanrajapuram, CC BY-SA 4.0)"

ANTIMICROBIAL ACTIVITY

Research also demonstrated that fermented Vechur and Kasaragod dwarf milk showed inhibitory activity against pathogenic bacteria such as Escherichia coli and Salmonella enterica (Jain et al., 2023). The functional property is enhanced during yoghurt fermentation, suggesting potential for probiotic-rich heritage milk products.

ADAPTIVE TRAITS AND HEALTH ADVANTAGES

Parasite Resistance

Controlled field trials conducted in Kerala (Devapriya et al., 2021) found significantly lower tick burdens in Vechur and Kasaragod dwarf cattle compared to crossbreds under identical management conditions. This innate resistance reduces the need for chemical acaricides, lowering costs and decreasing the risk of chemical residues in the environment

Heat Tolerance

Observational and physiological studies show that miniature zebu breeds maintain stable body temperatures and feed intake during heat stress periods (Upadhyay et al., 2019). This is due to their smaller body mass, lighter coat colour and greater surface area-to-body weight ratio.

Feed Efficiency

Ramesh et al. (2022) reported that Kasaragod dwarf cattle possess a rumen microbiome enriched in fiber-degrading bacteria, enabling efficient digestion of low-quality forages. This allows sustained productivity in areas where high-quality feed is scarce, an advantage for resource-poor farmers.

Economic and systems implications

LOWER INPUT, LOWER RISK

Due to the low feed requirements and natural parasite resistance, miniature breeds incur significantly lower veterinary costs than crossbreds (Devapriya et al., 2021). Even with lower milk yields, the net profit margin can be higher in smallholder systems because input costs are minimal (NBAGR, 2021).

PREMIUM PRODUCT POTENTIAL

The high fat content of Punganur milk (~8%) (NBAGR, 2021) and the antioxidant-rich profiles of Vechur and Kasaragod dwarf (Jain et al., 2023) position these breeds for niche marketing like A2-certified ghee, probiotic yoghurt and traditional sweets. Consumer willingness to pay more for functional and heritage products is a documented trend in urban Indian markets (FSSAI, 2022).

CLIMATE-RESILIENT DAIRYING

With climate change expected to intensify heat stress and fodder shortages, miniature breeds are ecological assets — they can maintain productivity under challenging agro-climatic conditions, making them suitable for climate-smart dairy initiatives (Upadhyay et al., 2019).

RESEARCH GAPS AND PRIORITY ACTIONS REQUIRED

1.Standardised lactation trials — Long-term, multi-location studies are needed to accurately benchmark yield and composition under varied feeding systems (Singh et al., 2020).

2.High-resolution compositional studies — LC-MS/MS metabolomics can reveal breed-specific nutritional advantages, as already demonstrated in Malnad Gidda (Ramya et al., 2020).

3.Genomic selection tools — Wider-scale B-casein genotyping could help maintain the A2 trait while improving productivity (Singh et al., 2022).

4.Value chain pilots — Linking miniature cattle farmers to branded A2/heritage product lines can demonstrate economic feasibility and consumer acceptance (FSSAI, 2022).

PRACTICAL RECOMMENDATIONS FOR FARMERS AND EXTENSION WORKERS

- For smallholders: Choose miniature breeds if you have limited land or resources; lower input costs often mean better

"Malnad Gidda cattle in their native hilly habitat of Karnataka (Photo: Wikimedia Commons user Pavanaja, CC BY-SA 3.0)"

Punganur cattle showing dwarf zebu conformation (Photo: Shaikmohammedhafiz, CC BY-SA 4.0)

profitability despite smaller volumes.

- For cooperatives: Develop local collection and branding strategies for heritage milk and ghee.
- For policymakers: Fund community breeding programs and market development for indigenous breeds to ensure their conservation and commercial viability.
- For researchers: Focus on breed-specific functional product development backed by rigorous compositional and health-benefit data.

CONCLUSION

Miniature indigenous cattle breeds such as Vechur, Kasaragod dwarf, Punganur, Nadipathy, and Malnad Gidda represent a synergy of tradition, resilience and functional value in Indian dairying. Their milk yield may be modest compared to exotic or crossbred cattle but their low-input adaptability, disease resistance and nutrient-rich A2 milk offer a distinct advantage for smallholder and climate-smart farming systems. The antioxidant and antimicrobial properties as well as the high total solids with exceptional fat content make them unique. Additionally, their smaller ecological footprint and cultural heritage value make them an integral part of a diversified dairy sector. Thus, promoting miniature breeds is not just about preserving biodiversity — it is about redefining dairy success in terms of profitability and health benefits, while honouring India's livestock heritage.

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