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& FARMERS' WELFARE, GOVERNMENT OF KERALA

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KERALA KARSHAKAN

E-JOURNAL

THE FIRST ENGLISH FARM JOURNAL FROM
THE HOUSE OF KERALA KARSHAKAN

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Urban Farming

Farming for the Future

INSIDE

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THE FIRST ENGLISH FARM JOURNAL FROM THE HOUSE OF KERALA KARSHAKAN

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Editorial

Urban Farming

Farming for the Future

Urbanisation is rapidly reshaping the way we live—and the way we produce food. With rising population, shrinking agricultural land, and increasing dependence on external food sources, cities are becoming both consumers and potential producers of food. The need to bring cultivation closer to where people live is no longer an option, but a necessity. Urban farming emerges as a practical and timely response, helping to bridge the gap between food production and consumption while strengthening food security in an uncertain world.

Today, agriculture is also transforming into a lifestyle choice. In urban spaces, farming is no longer limited by land availability. Rooftops, balconies, and small courtyards are being reimagined as productive green spaces. With the support of smart technologies, including sensor-based systems and precision farming tools, even limited spaces can be used efficiently. Urban

farming not only ensures access to safe, chemical-free food but also contributes to physical well-being and mental health, especially in fast-paced city life.

Experiences from around the world show that cities can successfully integrate farming into their infrastructure. As land becomes scarce and climate challenges intensify, innovative approaches such as vertical farming, rooftop cultivation, and integrated systems are gaining importance. At the same time, urban farming encourages community participation, reconnects people with nature, and promotes sustainable living practices among younger generations.

This issue focuses on the growing relevance of urban farming and its role in shaping the future of agriculture. You can read more about its possibilities and practices in the pages that follow. As we move forward, the path is clear: making cities greener and more self-reliant in food production is essential for building a resilient, sustainable, and future-ready agricultural system.

EDITOR

Urban Agriculture
An Imperative of Our Times

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According to estimates released by the United Nations, the global population is expected to reach 9.7 billion by 2050, and more than 68 per cent of this population will be living in urban areas. This means that global food production will have to increase by nearly 70 per cent. At the same time, the shrinking availability of agricultural land has created a global food-land paradox. Climate change, water scarcity and insecurity in food supply chains have further intensified the challenges to global food security.

Kerala is passing through a decisive phase in its agricultural sector. According to the 2011 Census, Kerala's urban population was 47.7 per cent; today it is estimated to be more than 55 per cent. Agricultural land is shrinking, holdings are becoming increasingly fragmented and urbanisation is accelerating. In cities such as Thiruvananthapuram, Kochi, Kozhikode and Thrissur, buildings and concrete structures are expanding while homesteads and green spaces are declining. At the same time, the demand for safe and pesticide-free vegetables is becoming stronger in urban areas. A major share of the food products required by Kerala still comes from other states. This situation poses a serious threat to the idea of food sovereignty.

The COVID-19 pandemic offered an important lesson to urban Kerala. Many families began cultivating food crops in courtyards, on terraces, in balconies, in pots and in grow bags, thereby creating a small but meaningful resilient wall for household food security. When the pandemic exposed the vulnerability of food chains, the understanding deepened across the world that food must first be produced as close as possible to human settlements. Reducing the distance between centres of production and consumption can also lay the foundation for a sustainable food system. Urban agriculture is one important response to this need.

What is Urban Agriculture?

Urban agriculture refers to all forms of cultivation and allied production systems within cities and their surrounding peri-urban areas. It includes the production of food crops, nutritious crops, medicinal plants and, in some contexts, fish, mushrooms and small livestock components. Urban agriculture is not a new idea for Kerala. What is new is its scientific design, technological scope, policy relevance, commercial potential, importance for nutritional security and role in climate resilience.

Urban agriculture may be understood as a food system that includes the growing, processing and distribution of food and non-food products within a city or its peri-urban region. A food system includes all activities associated with food production, processing, distribution, marketing, consumption and waste management. Production is not confined to crop cultivation alone; it also includes allied activities such as fisheries, livestock rearing, mushroom cultivation and beekeeping. In addition to marketing, distribution, storage and consumption, a food system also includes questions of when and how people access food, how waste is managed, and the related social, technological, economic, cultural and environmental issues.

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The globalised food system, concentrated in large agribusiness institutions and multinational companies, has steadily pushed local food production to the margins. As a result, consumers have increasingly had to depend on global markets for their food. Food supply chains are the links that connect different components of the food system. Short food supply chains have now been recognised in global climate and food security discussions as a practical and beneficial strategy. When food is produced, consumed and waste-managed within cities themselves, short food supply chains are created. This area certainly requires greater technological progress and investment.

It is estimated that economically weaker sections of our nation spend nearly 50 to 70 per cent of their total income on food. If households produce at least a part of what they consume, they can reduce expenses and generate income by selling surplus produce. Studies indicate that if every household engages in food production according to its own capacity, whether vegetables, fruits or tubers, an average city can achieve 10 to 15 per cent food self-sufficiency. More importantly, families gain access to safe, pesticide-free food. Urban agriculture also offers hope for densely populated areas where land is extremely limited.

Compared with rural agriculture, urban agriculture is distinct because of its limited cultivation space, proximity to consumers, use of pots, containers and rooftop systems, and close connection with households and institutions. Therefore, urban agriculture is not merely 'small-scale farming'; it is a specialised agricultural system suited to urban life.

Environmental Benefits of Urban Agriculture

1. Food Miles

A food mile is the distance travelled by a food product from its place of production to the place where it is consumed. In India, an average food product travels nearly 500 to 1,500 kilometres before reaching the consumer. If cities become as

self-reliant as possible, this distance can be reduced, leading to lower fuel use and reduced greenhouse gas emissions. In this way, urban agriculture can contribute to global efforts to address climate change. This is why it deserves major attention in climate-resilience strategies.

2. Waste Management

Most cities are facing a serious waste-management crisis and urban agriculture is a solution to overcome this problem through the concept of circular economy: waste must be processed as close as possible to the point of generation. Kitchen waste and other biodegradable materials can be converted into vermicompost, compost or biogas slurry and then used for cultivation.

3. Urban Heat Island Effect

Concrete buildings and the heat released by air conditioners are turning urban areas into heat islands. Rooftop gardens, green walls and indoor gardens can reduce the temperature of buildings in urban areas by 5 to 10 degrees Celsius. They can also reduce electricity consumption for air conditioning and significantly lower the carbon footprint of cities.

4. Biodiversity

Rooftop gardens, homestead gardens and community gardens support butterflies, bees, birds, soil microorganisms and other living organisms. They create small but valuable ecosystems and contribute to urban biodiversity.

Why is Urban Agriculture Particularly Suitable for Kerala?

In Kerala, where land is expensive and holdings are small, space-saving farming systems have great significance. Urbanisation, land fragmentation and loss of cultivated land are major challenges to food production.

Kerala still brings in a large volume of vegetables from neighbouring states. This creates price fluctuations, supply disruptions, concerns about pesticide residues and loss of freshness. Urban and peri-urban agriculture can reduce this dependence.

Kerala's tradition of homestead cultivation provides a strong foundation for urban agriculture. Growing banana, moringa, papaya, curry leaf, chilli, turmeric, tubers and leafy vegetables around the house is part of the state's natural food culture.

Grow bags, pots, kitchen-side medicinal gardens, and compost-based nutrition gardens can be easily established on homesteads and terraces. Rooftops and shared spaces in apartment complexes can be used for collective vegetable cultivation, rooftop production units and integrated compost-cultivation cycles. Schools, colleges, hospitals, government offices and places of worship can establish nutrition gardens, medicinal plant blocks, hydroponic demonstration units and compost-based cultivation systems.

Market-oriented urban agriculture may include hydroponic leafy-vegetable units, microgreens, mushroom cultivation, commercial rooftop farming, production of leafy vegetables for hotels, and peri-urban vegetable clusters. Kerala's humid and rainy climate, active local self-government institutions, Kudumbashree, Krishi Bhavans and Kerala Agricultural University together provide a favourable environment for scaling up urban agriculture across the state.

What Can Be Cultivated in Urban Areas?

In Kerala's urban and peri-urban areas, it is essential to select crops that provide higher returns from limited space. Leafy vegetables such as amaranthus, pulses, coriander and mint are highly suitable for urban agriculture because they can be harvested within a short period.

Common vegetables such as okra, cowpea, chilli, tomato, brinjal, bitter gourd, snake gourd, bottle gourd, cucumber and ridge gourd can be successfully grown in grow bags and small beds.

Medicinal and aromatic plants such as tulsi, curry leaf, Indian borage, lemongrass, aloe vera and turmeric are useful for regular household needs. Container-friendly crops such as papaya, dwarf banana, lemon, guava and passion fruit can support family nutrition and also enhance household aesthetics.

Mushroom cultivation and microgreens production offer quick returns from very small spaces and are suitable for women- and youth-led enterprises.

In Kerala, where land is expensive and holdings are small, space-saving farming systems have great significance. Urbanisation, land fragmentation and loss of cultivated land are major challenges to food production.

Technologies Transforming Urban Agriculture

At the initial stage, rooftop cultivation is one of the most practical options for Kerala. However, waterproofing, drainage, load management, lightweight grow bags, trellis systems, drip irrigation and rainwater harvesting must be carefully considered. Vertical farming is suitable for urban homes with limited space. Wall units, racks, pipe-based structures, modular frames and trellises can help increase production.

Hydroponics is the method of growing plants without soil, using a nutrient solution. Leafy vegetables, herbs and certain specialised vegetables can be produced using systems such as the Nutrient Film Technique (NFT), Deep Water Culture (DWC), media beds and Dutch buckets. While hydroponics offers advantages such as water efficiency, cleanliness and precise nutrient management, it also involves challenges such as initial investment and the need for technical skill.

Aquaponics, net houses, rain shelters, polyhouses and small protected structures can make urban agriculture more stable. Protected cultivation is particularly relevant in Kerala because of the state's heavy rainfall.

Kitchen-waste composting, vermicomposting, leaf-litter composting and the use of biogas slurry can transform urban agriculture into a circular system.

Is Urban Agriculture Economically Viable?

At the household level, the benefits of urban agriculture are not limited to money. It helps reduce expenditure on vegetables and also improves the mental and physical well-being of family members.

With the right model, urban agriculture can become a strong small enterprise. Potential areas include hydroponic leafy vegetable production, microgreens, mushroom cultivation, seedling production, terrace garden installation services, potting-mix preparation, composting services and herb supply chains.

Peri-urban agriculture must provide strong support to urban markets. Food security can be ensured only when small-scale production within cities is combined with wider vegetable production in the surrounding peri-urban areas.

Policy Formation

Kerala has the potential to become a national model in urban agriculture. This requires coordination among the Department of Agriculture, local self-government institutions, Krishi Bhavans, Kudumbashree, Haritha Karma Sena, Suchitwa Mission, VFPCK, schools and residents' associations. Urban farmers must receive accurate and integrated services through a single-window system that coordinates these agencies. A Kerala Urban Agriculture Policy is essential for this purpose.

Kerala Agricultural University can play a decisive role in training urban farmers, developing terrace-farming packages, standardising grow-bag media, preparing hydroponic guidelines, managing pests and diseases, issuing safe food production protocols, developing organic waste-fertiliser cycle models and providing entrepreneurship training.

Future policy interventions should include ward-level urban agriculture plans, incentives for rooftop farming, apartment gardens, special support for women- and youth-led enterprises, school urban agriculture modules and a trust mark for safe urban produce.

Challenges

Not all households have adequate space. Expanding rooftop cultivation without ensuring load-bearing capacity, waterproofing and drainage can be risky. Initial costs, time constraints, market instability, poor quality of inputs and lack of training are also major challenges. Water availability and water quality, including hard water, pollution and summer scarcity, can affect urban agriculture.

Lack of scientific knowledge in pest and disease management, loss of continuity after initial enthusiasm, market problems, poor input quality and weak inter-departmental coordination are additional constraints. These are not reasons to avoid urban agriculture; rather, they show the need for stronger scientific and policy-based support.

Goals

Kerala must move towards a future in which leafy vegetables grow in every urban household, every apartment complex has a collective food garden, every school has a nutrition garden and every corporation or municipality prepares a rooftop and vacant-space map suitable for cultivation.

Kudumbashree units can lead urban food enterprises. Young people can build start-ups in hydroponics, microgreens, mushrooms and edible landscaping. The peri-urban zones around cities can become productive vegetable belts.

The time has come to see cities not merely as centres of consumption but also as centres of production, nutrition and regeneration. This shift is necessary to address shrinking agricultural land, rising urbanisation, people's demand for safe food, the pressure of climate change and the crisis of urban waste management.

Kerala has all the elements required to make progress in this field: homestead farming traditions, a literate and scientifically aware population, strong local institutions, participation of women's collectives, an active extension system and the scientific support of Kerala Agricultural University.

When these elements come together, urban agriculture can give Kerala safe and nutritious food, greener cities, local solutions for biodegradable waste, new opportunities for women and youth entrepreneurs, better family health, stronger social cohesion and greater urban food resilience.

In household cultivation, whether on terraces or in spaces around the home, the labour used is often that of family members. If children are also included, it becomes one of the most valuable forms of practical learning for them. Home gardens can become spaces of togetherness that nurture mutual affection and respect. When cultivation is taken up in parks, vacant spaces, schools or offices, it also creates social capital through collective action.

Recognising the importance of sustainable urban agriculture, Kerala Agricultural University has established a dedicated Centre for Urban Agriculture at the College of Agriculture, Vellayani, Thiruvananthapuram. In view of the importance of this emerging field, Kerala Agricultural University is also launching a postgraduate programme in Urban Agriculture at the College of Agriculture, Vellayani. ■

A New Era of Smart Farming in Cities

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Agriculture today is no longer merely a means of livelihood. It has increasingly become the foundation of a healthier lifestyle for the new generation. When technology is integrated into farming, it marks the beginning of a new era. Even in highly space-constrained urban settings, city dwellers are now finding room for cultivation. More than just a source of income, smart farming enables urban residents to access safe food and experience mental well-being through a modern and efficient cultivation system.

Many of the challenges associated with conventional agriculture—limited space, water scarcity, lack of time, and climate change—can be effectively addressed through Internet of Things (IoT)-based smart farming systems. By adopting these technologies, farmers can ensure higher income as well as better product quality.

Important Sensors and Their Uses

Sensor	Application	Significance
Soil Moisture Sensor	Measures soil moisture levels	Ensures water is supplied only when needed and in the required quantity, thereby preventing water wastage
Temperature and Humidity Sensor	Measures ambient temperature and humidity	Helps maintain ideal growing conditions in greenhouses and indoor farms
Light Intensity Sensor (LDR / Lux Sensor)	Measures the intensity of sunlight or LED light	Regulates the amount and duration of light needed for plant growth; especially essential in vertical farming
pH Sensor	Measures the pH of nutrient solution (in hydroponics) or soil	Ensures the correct acidic or alkaline balance needed for plants to absorb nutrients efficiently
EC Sensor (Electrical Conductivity)	Measures salinity or fertilizer concentration in nutrient solutions	Helps ensure the crop receives nutrients in the right quantity and enables precision fertilization
CO_2 Sensor	Measures carbon dioxide concentration in the atmosphere	Regulates CO_2 levels required for photosynthesis in controlled environments
NPK Sensor	Detects levels of Nitrogen (N), Phosphorus (P), and Potassium (K) in soil	Supports crop health, productivity, cost reduction, and sustainability while also reducing environmental pollution

The Data Revolution

Data is the foundation of smart farming. A smart farm is a system in which information is collected through various sensors, analyzed, and used to automatically carry out necessary actions at the right time. In smart farming, the cultivation space becomes a data collection hub. This enables each plant to receive only the exact amount of water and nutrients it needs at each stage of growth—a practice known as precision fertilization.

Through this approach, farmers can reduce water and fertilizer use by 40% to 60%. Accurate data collection and automation make farming simpler, more efficient, and more profitable, especially for urban farmers.

A. Key IoT Sensors in Smart Farming

Sensors are the "eyes and ears" of a smart farm. They record even the smallest changes in real time. Parameters such as soil moisture, atmospheric temperature, humidity, light intensity, water pH, and electrical conductivity (EC) can all be monitored continuously through sensors installed in the cultivation unit.

B. Gateway and Cloud Connectivity

The data collected by sensors is transmitted to the internet through a gateway, using communication technologies such as Wi-Fi, LoRaWAN, GPRS, 3G, or 4G. This information can be stored in cloud servers, making it possible to preserve records and analyze them later as needed.

C. Automation Devices (Actuators)

Actuators are the devices that respond to sensor data and control farm conditions accordingly. For example, if soil moisture drops below a threshold, the automatic drip irrigation pump can be turned on; if temperature rises excessively, a fogger or cooling fan can be activated.

Types of Automation Devices

1. Automatic Pumps and Solenoid Valves: Used to start or stop irrigation based on soil moisture data. In hydroponics, they also regulate the supply of nutrient solution to plants.

2. Foggers and Sprinklers: Operate automatically to cool the environment and maintain the required humidity when temperature or humidity becomes excessive.

3. Automated Fans and Ventilation Systems: Remove hot air and allow cool air to circulate in greenhouses and indoor farms.

4. Grow Light Systems: Essential in vertical farming. Based on sensor data, the system can regulate light spectrum, intensity, and duration according to the

crop's growth stage. LED grow lights can switch on automatically when light is insufficient and off when adequate light is available, ensuring proper photoperiod management while reducing electricity consumption.

5. Solar Energy for Automation: Irrigation, lighting, and climate control systems can also be automated using solar energy.

6. Mobile Applications: Farmers can monitor and control every aspect of their farm from anywhere using a smartphone.

Thus, through smart farming, each plant can receive exactly the right amount of water and nutrients at the correct stage of growth, reducing water and fertilizer use by 40% to 60%.

2. High-Tech Smart Farming Models Suitable for Urban Areas

For urban farmers, the most suitable systems are those based on Controlled Environment Agriculture (CEA), primarily because of space limitations.

A. Hydroponics and Aeroponics

These are methods of growing plants without soil, using water or air, and are ideal for producing more in less space.

1. **Hydroponics:** Cultivation without soil, using a nutrient solution dissolved in water. It is highly suitable for rooftop farming.

2. **Aeroponics:** In this method, plant roots are suspended in air and supplied with nutrient solution in the form of a fine mist. This can reduce water use by up to 90% and accelerate plant growth. With IoT sensors, parameters such as pH and EC can be precisely maintained.

B. Vertical Farming

Vertical farming involves growing crops in multiple stacked layers inside buildings. This helps maximize yield per square foot and is highly suitable for urban environments where space is limited. Vegetables and herbs can be cultivated on vertical shelf structures in compact spaces.

Using IoT-based sensors, parameters such as soil moisture, nutrient status, temperature, and light intensity can be continuously measured, ensuring precise irrigation and nutrient application.

Mobile Applications and AI-Based Analysis

Dedicated agricultural mobile applications help farmers predict harvest timing, disease incidence, and pest risks.

Kerala Agricultural University has developed the Farm Extension Manager app, which provides cultivation practices for around 100 crops and information on nearly 2,000 diseases, pests, and nutrient deficiencies. These resources are highly useful even for urban terrace gardens and small-scale vertical farms.

The Crop Pest Surveillance System (CPSS) of the State Department of Agriculture conducts pest and disease surveillance and provides early warnings and scientific advisories.

The E-Crop Doctor application helps identify plant diseases and pest infestations, enabling urban farmers to detect problems early and adopt suitable control measures.

The AIMS Kerala app helps farmers access government schemes, subsidies, and official support systems.

Weather forecasting is also extremely important in agriculture. Even in urban settings such as terrace farming, hydroponics, and polyhouse cultivation, the Meghdoot app offers highly practical weather-based advisories. Irrigation and nutrient application can be adjusted based on rainfall probability, temperature, and humidity.

The combination of mobile applications and AI systems can provide urban farmers with timely and precise agricultural support, helping them maximize limited resources and produce safe, high-quality outputs.

Benefits of Smart Farming for Urban Farmers

1. **Premium Produce, Premium Price:** The quality and safety of produce grown under IoT-controlled systems often ensure better market value. Labels such as "chemical-free" and "data-driven cultivation" enhance consumer trust and acceptance.

2. **Resource Efficiency:** IoT automation helps prevent wastage of water, electricity, and fertilizers. This reduces operating costs and promotes environmentally sustainable farming.

3. **Time Saving:** Because the system is automated through sensors and actuators, the farmer's direct involvement is reduced. One can monitor and manage operations through a mobile phone, which is especially useful for urban farmers.

4. **Predictive Farming:** Using Artificial Intelligence (AI)-based data analysis, it becomes possible to predict pest infestation and nutrient deficiencies before they occur, allowing preventive action and reducing crop loss.

5. Investment and Return on Investment (ROI)

Smart farming systems require a higher initial investment.

However, if implemented thoughtfully, urban farmers can recover this investment relatively easily.

1. **Increased Yield:** Since crops can be grown year-round under controlled conditions, yields can be three to four times higher than in conventional farming.

2. **Reduced Operating Cost:** Lower use of water, fertilizers, and pesticides significantly reduces production costs.

3. **Premium Markets:** Selling produce to supermarkets, five-star hotels, and premium residential communities can ensure higher profit margins.

Experiences from Indian cities over the past decade indicate that IoT-based smart farming is no longer just a hobby. It is increasingly becoming an essential and viable enterprise for sustainable urban living.

Conclusion

When urban residents turn to farming with the objective of producing high-quality, profitable produce in limited space, using minimal resources and less time, the technology that guides them is undoubtedly the Internet of Things (IoT).

It is these smart tools that are giving life to high-tech cultivation systems such as hydroponics and vertical farming on rooftops and balconies in cities.

Smart farming is not merely a technological trend; it is a practical pathway toward better food quality, higher efficiency, resource conservation, urban sustainability, and a healthier and more resilient future. ■

COVER STORY

Rooftop Cultivation

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Living a healthy and peaceful life is something all of us aspire to. In pursuit of that goal, we engage in many activities. Among them, one of the most rewarding—both mentally and physically—is cultivation. Some readers may wonder what is new about that. Others may ask: when many Malayalis are moving into flats due to lack of land even to build a house, where is the space for farming?

That is a valid question. Yet, think for a moment: can the joy you feel when you pluck a mango from the tree in your own yard, ripen it, and eat it yourself—or share it with others—ever be the same as buying mangoes for one or two hundred rupees from the market? Can the taste of a honey-sweet jackfruit harvested from the grafted dwarf jack tree in your own compound ever be matched by a jackfruit bought for four hundred rupees? The answer, for most of us, is no.

If that is so, why not make use of the small spaces available to us—whether in the courtyard, balcony, or rooftop—to grow such plants? The people who should be involved most in this effort are our children. Just as schools now promote activities like Zumba to improve children's physical and mental well-being, we can also hand over five plant pots to a child and ask them to

For those who cannot pursue conventional agriculture due to lack of land, rooftop cultivation offers a practical way to engage in farming and reconnect with nature. Growing vegetables in terraces using grow bags helps ensure household food security. It can also provide additional income for homemakers and others who take up rooftop farming. In an era when organic farming is being widely encouraged, rooftop cultivation using biodegradable waste and organic practices can reduce pollution and ensure access to safe, chemical-free food.

For rooftop cultivation, it is advisable to use High-Density Polyethylene (HDPE) containers or grow bags that are durable and can withstand climatic stress to a certain extent. Since these containers are lightweight, they are ideal for vegetable cultivation on terraces. Grow bags should be filled with a suitable potting mixture and placed on the terrace after carefully identifying the beam positions. They should be placed on bricks or similar supports rather than directly on the roof surface. Proper irrigation must then be ensured. Care should also be taken to prevent water stagnation and to keep the terrace clean and well-drained.

Generally, grow bags of 40 cm × 24 cm × 24 cm, made of 150-micron (60-gauge) material, are widely used for cultivation. Approximately 75 grow bags of this type—white on the outside and black on the inside—can be accommodated in one cent of area.

On average, about 12 kg of potting mixture is required for each grow bag. Before filling the bags, it is essential to conduct a soil test. This helps determine soil acidity or alkalinity and the status of nutrient elements. If the soil pH is below 5.5, the

grow a few vegetables. Those pots may be placed on a balcony. If you have a rooftop, you are fortunate. Let children plant the seedlings, watch them grow, observe the flowering, fruit setting, and ripening, and finally harvest the produce themselves. In today's family environments, emotional imbalance and stress among children are increasingly common. A small balcony or rooftop garden can become a healing space for the entire family—a place of togetherness, restoration, and joy.

For rooftop cultivation, it is advisable to use High-Density Polyethylene (HDPE) containers or grow bags that are durable and can withstand climatic stress to a certain extent.

addition of dolomite or lime becomes necessary.

Another important practice is soil solarization. This involves covering moist soil with a transparent plastic sheet during periods of strong sunlight so that the soil gets disinfected through solar heat. This process helps eliminate soil-borne fungal pathogens, nematodes, weeds, and other harmful organisms.

For each grow bag, about 100–150 g of dolomite may be added to the potting mixture. After mixing thoroughly, the mixture should be moistened. Cultivation should begin only after 10–14 days. Apart from reducing acidity, dolomite also adds calcium and magnesium to the soil. Ideally, dolomite should be applied based on soil test recommendations.

It is also beneficial to add 15 g of Trichoderma-enriched farmyard manure to the mixture. Along with this, for each bag, add 100 g bone meal, 100 g ash, 100 g neem cake, and a small quantity of chopped coconut husk. Using this mixture, fill about three-fourths of the grow bag. If sacks are used instead of grow bags, proper drainage must be ensured.

Tall plants should preferably be placed on the western side, while shorter plants should be arranged on the eastern side for better light exposure and healthy growth. Bags should never be placed directly on the terrace surface. They may be arranged along the parapet wall, keeping the base slightly inward. Two bricks may be placed parallel to each other, or three bricks may be arranged in a triangular stove-like pattern, and the bags may be placed on top.

For the first 10 days, watering may be done on alternate days. If weeds sprout, they should be removed before sowing seeds or transplanting seedlings. Crops such as okra, amaranthus, cowpea, ivy gourd, snake gourd, and tuber crops can all be successfully grown under suitable seasonal conditions.

For cucurbit crops such as cucumber and gourds, up to four seeds may be sown in one bag. After about two weeks, only the two strongest seedlings should be retained.

Seedlings of brinjal and related vegetables may be transplanted 15–20 days after sowing, provided they are from varieties with good tolerance to wilt. Before transplanting, dipping the seedlings in a solution of Pseudomonas (20 g per litre of water) is recommended. Newly transplanted seedlings should be given shade for about one week.

In organic cultivation, the emphasis should be on preventive care rather than curative measures after pests and diseases appear. When plants have 4–5 leaves, the following may be sprayed once a week: 2% neem oil-garlic emulsion and Pseudomonas solution (20 g per litre of water). A solution prepared using turmeric powder at 4 g per litre of water can also help protect plants. Diluted rice gruel water may also be sprayed, as it is beneficial to plant health.

Organic liquid manures such as cow dung slurry (1 kg in 10 litres of water) may be applied. Cow urine and vermiwash can be diluted at the rate of 1 litre in 10 litres of water and used. Applying vermicompost once a week also promotes healthy growth.

During rainy periods, only limited watering is required. If the rooftop becomes excessively hot, shade nets may be used to regulate temperature.

To make rooftop farming more attractive and multifunctional, Azolla, often called "nature's protein tablet," may also be cultivated. It can be grown in tanks or pits measuring about 1 metre in width, 2 metres in length, and 1 foot in depth.

Rooftop cultivation can also be effectively integrated with

A Suggested Rooftop Layout for a Small Family

To ensure a nutritionally rich and balanced vegetable supply for a family, it is useful to grow crops from different categories such as leafy vegetables, tubers, and fruit vegetables. A suggested layout is given below:

Category / Crop	Number of Pots / Grow Bags
Leafy vegetables	10
Tuber crops	15
Tomato	4
Green chilli / Bird's eye chilli	4
Brinjal / Eggplant	5
Okra	5
Snake gourd	2
Cowpea	8
Bitter gourd	2
Curry leaf	2
Coriander	1
Mint	1
Pumpkin	1
Cucumber	2
Passion fruit	1
Drumstick (Moringa)	1
Ivy gourd	1
Total Pots / Grow Bags	65

organic waste management. Installing biogas units on rooftops helps process food waste. The gas produced can be used as cooking fuel, while the slurry can be used as manure for plants. Similarly, small vermicompost units and household kitchen compost systems can be integrated into rooftop gardens, ensuring both waste recycling and a steady supply of organic manure.

One of the most important aspects of rooftop cultivation is irrigation management. Plants must receive adequate water, but over-irrigation can cause water stagnation, which may eventually damage the rooftop. Drip irrigation is therefore highly desirable.

When the house is locked or unoccupied, a simple method can be adopted: fill a cup or plastic bottle with water, make two or three tiny holes in it, and place it near the base of the plant. Wick irrigation and drip systems are also useful in ensuring measured water supply and avoiding wastage. Along with any irrigation method, it is equally important to provide nutrients to plants at the right time.

Rooftop cultivation plays a significant role in achieving self-sufficiency in vegetable production. Kerala has approximately 75 to 80 lakh operational holdings. Household food security can be substantially strengthened if rooftop cultivation is adopted in every home.

A family generally requires about 325 to 425 kg of vegetables per year. If a household maintains 60 to 80 pots or grow bags on its rooftop, it can produce enough vegetables to meet much of this annual requirement.

Kerala is moving rapidly along the path of modernization and urbanization, and the number of urban residents continues to rise. Compared to many other states, the shortage of land available for agriculture is a major challenge to Kerala's food security. This challenge can be addressed, at least in part, by cultivating available spaces in urban homes. This is where urban agriculture becomes highly relevant.

As urbanization expands in towns and cities, the agricultural sector often recedes. But if each household can secure its own food needs through cultivation, it becomes possible to strengthen food self-reliance at the state level itself.

Conclusion

Rooftop cultivation is not merely a method of growing vegetables in limited space; it is a practical and meaningful pathway toward household food security, healthier lifestyles, waste recycling, environmental sustainability, and family well-being. In a state like Kerala, where land is scarce and urbanization is expanding rapidly, rooftop farming offers a realistic and scalable solution. If widely adopted, rooftop cultivation can transform urban homes into productive green spaces, reduce dependence on external markets for vegetables, strengthen food resilience, and reconnect people—especially children—with nature, nutrition, and the dignity of growing one's own food. ■

Novel fertilizers for urban farming

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The transformation from vast stretches of paddy fields to dense building complexes has occurred rapidly. Changing lifestyles, busy work schedules, and other factors have widened the gap between people and agriculture. For urban residents, especially those living in flats and apartments, limitations of space and time pose significant challenges to practicing farming.

At the same time, awareness about healthy food is steadily increasing. The idea of producing safe, chemical-free vegetables at home is encouraging people to reconnect with agriculture. As a result, terrace gardening and balcony farming are gaining popularity in urban areas.

However, urban farmers often face several challenges, one of the major ones being fertilizer application. The use, storage, and availability of conventional bulk fertilizers can be inconvenient, discouraging many from continuing these practices. In this context, modern techniques such as foliar spray and drip irrigation are emerging as practical solutions. These methods enable efficient nutrient delivery along with irrigation, making them highly suitable for urban farming.

To support such systems, IFFCO has introduced innovative products such as nano fertilizers, water-soluble fertilizers, and bio-stimulants. These inputs supply essential nutrients to plants in very small quantities with high efficiency. Nano fertilizers such as Nano Urea, Nano DAP, Nano Zinc, and Nano Copper—developed using advanced nanotechnology—play a crucial role in improving plant growth and productivity.

Nano Urea (20% N w/v), when applied as a foliar spray at 5 ml per liter of water, provides essential nitrogen during the vegetative stage of plants, significantly enhancing plant growth and yield. Nano DAP, which contains nitrogen and phosphorus, can be applied through three methods: seed treatment, root treatment, and foliar spray:

Seed treatment: Mix 3–5 ml of Nano DAP per kg of seeds with a small quantity of water, coat the seeds, and sow after 30 minutes. This improves germination. Root treatment: Mix 3–5 ml per liter of water and dip the roots of seedlings for 30 minutes before transplanting. This ensures better establishment and growth. Foliar spray: Apply 5 ml per liter during the vegetative stage to enhance growth and flowering

Micronutrients like zinc and copper can be supplied through Nano Zinc and Nano Copper at 1 ml per liter, preferably along with the first spray. These help improve root development, nutrient absorption, fruit setting, and resistance to pests and diseases.

In addition to nano fertilizers, water-soluble fertilizers such as NPK 19-19-19, Potassium Nitrate (13-0-45), and Potassium Sulphate (0-0-50) can be applied at 5–10 grams per liter at different growth stages.

Bio-stimulants like Sagarika Seaweed Extract and Dharamrit also play a significant role in urban farming. Sagarika contains essential nutrients, micronutrients, plant growth hormones such as auxins, cytokinins, and gibberellins, along with proteins and humic acids. When applied at 5 ml per liter, it promotes overall plant growth, enhances nutrient uptake, improves chlorophyll content, and improves the size, color, and taste of produce

Dharamrit is another effective bio-stimulant containing alginic acid, amino acids, and carbon compounds. It enhances photosynthesis and improves the size, weight, and quality of grains, vegetables, and fruits. It also strengthens plants to withstand various climatic conditions. It can be applied as a foliar spray at 5 ml per liter.

Applying nutrients through foliar spray or fertigation methods such as drip irrigation and wick irrigation is simpler and more efficient compared to conventional practices. IFFCO's innovative fertilizers enable urban farmers to achieve better yields even within the constraints of limited space and time. ■

From Concrete to Crops

What Kerala Can Learn from Singapore's Urban Farming Revolution

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Figure 1 Around 60 varieties of herbs, vegetables, and fruits are cultivated in the rooftop garden of the Parkroyal Collection Marina Bay hotel (© Masano Kawana).

On a humid morning in Singapore, long before the city's offices come alive, something unusual is already in motion above the skyline. Rooftops, parking structures, and even old buildings are quietly producing food. Leafy greens grow in stacked layers, fish are raised in controlled systems, and vegetables thrive without soil. In a country where land is scarce, farming has not disappeared, it has simply moved upward and inward. For Kerala, this story is not as distant as it may seem. Our cities are expanding rapidly, agricultural land is shrinking, and dependence on food imports continues to rise, not just for vegetables, but also for eggs, milk, and other essential food items. Singapore, facing similar vulnerabilities, has begun actively prioritising local production of vegetables, eggs, and fish as part of its food security strategy.

At first glance, comparing Kerala with Singapore may seem unusual. Kerala is geographically much larger, while Singapore is a compact city-state. Yet, the comparison is meaningful. Both share a humid tropical climate, high population density in urban regions, and increasing pressure on land resources. More importantly, both are navigating the challenge of ensuring food security under conditions of rapid urbanisation. What Singapore has done is not just innovation, it is a response to necessity. And in many ways, that necessity is beginning to look familiar.

When scarcity forces innovation

Singapore produces less than 10% of its nutritional needs locally, while nearly 90% of its food comes from imports. This heavy dependence worked for years, but global disruptions, especially during COVID-19, revealed how fragile long supply chains can be. In response, Singapore set a clear goal: to produce 30% of its nutritional needs locally by 2030. But with only about 1% of land available for conventional farming, the country had to rethink agriculture itself. Instead of expanding farmland, Singapore chose a different path, growing more food within the city. Kerala may not face such extreme land scarcity, but the pattern is similar. Urban expansion, fragmentation of holdings, and declining interest in farming are slowly reducing local production. The lesson here is simple: waiting for more land is not a solution, using existing space better is.

Farming without fields: How the city became productive

In Singapore, agriculture no longer looks like open fields. It is integrated into the urban fabric. One of the most practical innovations is rooftop farming. Parking structures, which exist in almost every neighbourhood, are now used to grow vegetables

Figure 3 Citiponics, Singapore's first hydroponics rooftop farms on top of a carpark

through hydroponic systems. Farms like Citiponics have demonstrated that rooftop systems can significantly increase productivity by using vertical arrangements and efficient nutrient delivery. Inside the city, buildings themselves are being converted into farms. Indoor vertical systems now operate within warehouses and repurposed industrial spaces, producing crops that would otherwise be imported.

Another important transformation is the redesign of greenhouse structures. Instead of traditional models, Singapore has adopted climate-adapted greenhouses with improved ventilation, shading, and cooling mechanisms suited to tropical conditions. These redesigned structures help regulate temperature and humidity more efficiently, reducing energy use while maintaining high productivity, an approach widely discussed in global platforms such as the World Economic Forum. Even unused public spaces are being repurposed. Old schoolyards, vacant plots, and underutilised urban land are converted into productive farming zones. What stands out is not just technology, but the mindset: any space, if thoughtfully used, can become productive. Equally important is

Figure 2 Indoor vertical farming infrastructure using hydroponics technology and a controlled environment agriculture (CEA) system by Sustenir.

the rise of community farming. Residents are increasingly involved in growing food within neighbourhood spaces, community gardens, and shared urban farms. These initiatives not only improve access to fresh produce but also strengthen social connections and awareness about food systems. In Kerala, rooftops, school compounds, office buildings, and even unused institutional land offer similar possibilities. While small-scale rooftop farming already exists, the Singapore model shows how it can move from scattered efforts to organised, community-driven systems.

Why vegetables, eggs, and fish matter most

Singapore's strategy is not to produce everything, but to focus on what matters most. The priority is on vegetables, eggs, and fish, foods that are widely consumed, highly perishable, and vulnerable to supply disruptions. Data also reflects this focus. Out of hundreds of licensed farms, a large share is dedicated to leafy vegetables and aquaculture systems, while only a small number are involved in general agriculture or livestock. This is an important lesson for Kerala. Urban farming does not need to replace traditional agriculture. Instead, it can strategically supplement it, especially in the case of: Leafy vegetables, short-duration crops, nutrient-rich perishable foods. These are exactly the commodities Kerala depends heavily on from outside states.

Technology as an enabler, not a luxury

A key strength of Singapore's approach is its use of technology to overcome limitations. Inside controlled environment agriculture (CEA) systems, factors like temperature, humidity, light intensity, and nutrient levels are continuously monitored and adjusted. LED lighting ensures optimal photosynthesis even in enclosed spaces. Automated irrigation systems deliver precise amounts of water and nutrients, minimising waste. Multi-layer vertical farms, LED lighting systems, and recirculating aquaculture setups allow production to increase several times compared to conventional

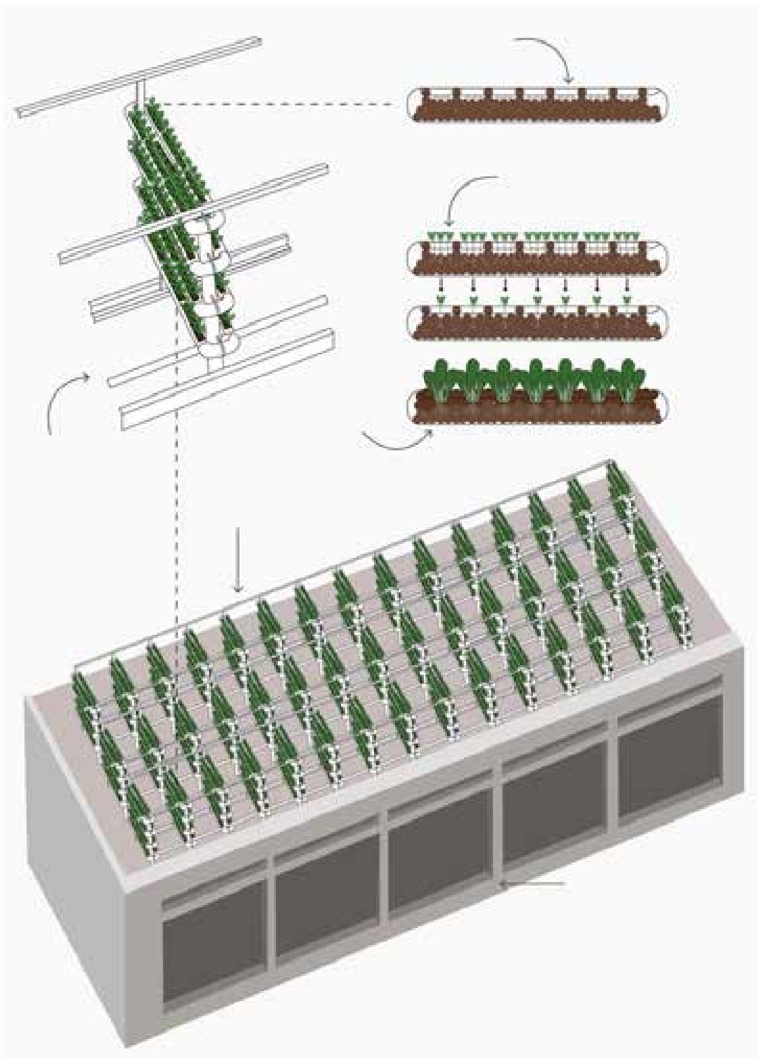

Figure 4 The Citiponics vertical rooftop system yields up to 4 times more than conventional farming.

farming. In some cases, yields can be 10 to 15 times higher per unit area. But what is important is not the sophistication alone, it is the efficiency. Water use is minimized, nutrient delivery is precise, climate risks are reduced, production becomes more predictable. Indoor vertical farms in Singapore are now using controlled environments not just to grow crops efficiently, but also to enhance their nutritional quality. In a compact facility of less than 4,000 square metres, farms have been able to produce nearly a tonne of leafy greens per day, such as kale and spinach. while even increasing beneficial compounds like gamma-aminobutyric acid (GABA), all without using pesticides.

For Kerala, the takeaway is not that every farmer must adopt high-tech systems. Rather, even simple versions of these technologies, adapted to local conditions, can significantly improve productivity in small spaces.

Policy support made the difference

Singapore's urban farming success is not accidental, it is strongly supported by policy. The government provides funding support, including large-scale grants for agri-tech enterprises, helping reduce the high initial cost of infrastructure. At the same time, land, though limited, is strategically allocated for high-efficiency farming projects. Urban farming is also encouraged at the community level, with citizens being seen as active contributors to food production. This coordinated approach, policy + technology + participation has been crucial. Kerala already has strong institutional frameworks like local self-governments and Kudumbashree. With targeted support for urban agriculture, training, subsidies, and technical guidance, similar momentum can be created.

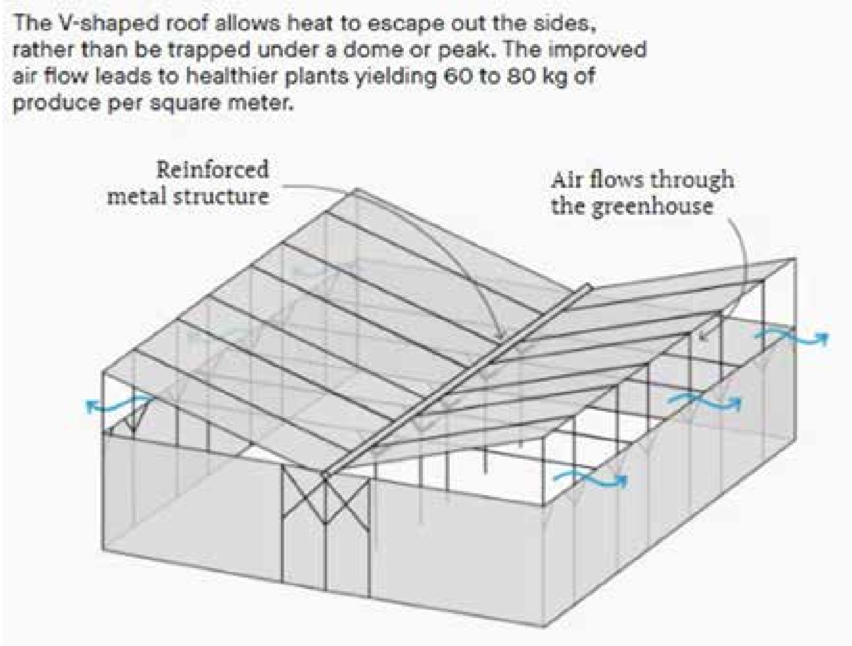

Figure 5 Natsuki's Garden is a greenhouse in the center of the city, occupying reused space in a former schoolyard.

The hidden challenges

Despite its progress, Singapore's model is not without concerns. High investment and energy use remain significant challenges. There are also concerns about whether high productivity always translates into long-term sustainability or profitability. Another important issue is the gradual displacement of traditional farmers, whose knowledge may be undervalued in a technology-driven system. These realities highlight an important point that the urban farming is not a replacement, but a complement to conventional agriculture.

What Kerala can take forward

The relevance to Kerala is clear. Urban farming here should not aim to replicate Singapore exactly, but to adapt its principles:

- Use rooftops and unused urban spaces productively
- Focus on vegetables and short-duration crops
- Promote small-scale hydroponics and protected cultivation
- Encourage community and institutional participation
- Support youth-led agri-enterprises

Most importantly, urban farming must be seen not as a hobby, but as a serious component of the food system.

Rethinking where food comes from

Singapore's experience challenges a long-held assumption, that farming belongs only in rural areas. It shows that with the right approach, cities too can produce a meaningful share of their food. For Kerala, the question is no longer whether urban farming is possible. It is whether we are ready to recognise its potential. As our cities continue to grow, the farms of the future may not lie far away. They may be right above us, on terraces, rooftops, and within the spaces we have long overlooked. ■

From Terrace to Table
The Growing Trend of Urban Poultry

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Poultry farming is one of the fastest-growing sectors in India's agriculture production system due to high demand for affordable eggs and meat. Although the commercial poultry production has evolved from an unstructured and unscientific system into a modern, tech-driven, and market-oriented enterprise, in urban areas of Kerala, the cage system is more suitable than backyard poultry farming.

Urban poultry farming is the rearing of poultry birds, mainly

chickens, ducks, or quails within cities or peri-urban areas for eggs or meat using small, manageable spaces like backyards, rooftops, or sheds. It is rapidly evolving due to changing lifestyles, technology, demand for fresh, local food and people's preference towards organic eggs and meat.

Total poultry population in the country is 851.81 million in 2019, an increase of 16.8% over the previous year, whereas the total backyard poultry in the country is 317.07 million in 2019, increased by 45.8% over the previous census. In 2019, there were 534.74 million commercial poultry in the nation, a 4.5 % increase over the previous census.

The total egg production in the country is 149.11 billion eggs during 2024-25. It has increased by 4.44% in 2024-25 as compared to the previous year. The per-capita availability of egg is 106 eggs per annum. Out of the total eggs produced, commercial poultry contributed 125.98 billion eggs, accounting for 84.49% of the national output. Backyard poultry, on the other hand, produced 23.13 billion eggs, representing 15.51% of the total production. India ranks 2nd in Egg production globally.

Urban poultry farming has significant scope in modern cities due to rising demand for fresh, safe, and locally produced eggs and meat. It provides an excellent opportunity for subsidiary income generation, especially for small-scale entrepreneurs, women, and youth, as it requires relatively low investment and can be practiced even in limited spaces such as backyards, rooftops, or terraces. It also offers mental relaxation and companionship other than economic and nutritional benefits. Composting poultry wastes, as well as dead birds, controls odours and provides an excellent fertilizer for gardens. Caring for birds can reduce stress, also pacifies the mind and creates a connection with nature as witnessed during the COVID-19 epidemics.

Urban poultry can be effectively integrated with other forms of urban agriculture, like vegetable gardening, enhancing overall productivity. Feed cost can also be reduced by efficient recycling of kitchen waste into feed other than commercial feeds. Automatic feeder and waterer ensure a continuous supply of feed, water and frequent manual attention is not required.

Housing can be done according to the space availability in the locality. Mainly backyard, rooftop or cage housing is preferable. Layers can be reared under cage housing, which makes handling easy. Native chickens such as Tellichery, Naked neck chicken are also preferred for small-scale production in urban landscapes.

Now a days homestead cages are available with automatic drinkers and feeders, making management easier and more cost-effective. With increasing support from government programs and advancements in technology, urban poultry farming is emerging as a climate-resilient and eco-friendly solution for strengthening urban food systems, despite challenges like space limitations, waste management, and disease control.

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From Cell to Cell
Mistry behind spread of viruses within plants

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Severity of plant diseases caused by virus depends on host, virus, their interaction, mode of transmission and environmental conditions. The highly virulent strain of virus replicates rapidly and move more efficiently through plasmodesmata to spread to other parts of the plants. These viruses also produce proteins having host defense suppression mechanisms. All these factors increase the viral load that helps in pronounced symptoms like mosaic, chlorosis, mottling, curling and stunting. Now a days in field mixed infections by two or more viruses may cause intensified expression and enhance the yield loss compared to single infection. Various host factors play a crucial role in determining disease severity. Susceptible plant varieties generally show more severe symptoms, while resistant genotypes can restrict viral replication and movement. The stage of plant at which the infection occurs is also important as early infection often causes greater damage than late infection. Environmental factors such as temperature, light intensity, nutrient availability, and vector population levels further influence symptom development and crop loss. So, there are many factors that determine the overall damage and impact of viral diseases on plant growth, productivity, and economic yield.

After entry via wounds or vectors, viruses uncoat and replicate in association with host endomembrane systems (Endoplasmic Reticulum, Golgi bodies, endosomes) or viral inclusion bodies.There are two types of movement; slow movement or local movement and fast movement or systemic movement. In local movement virus move to adjacent or neighbouring cells ie., local movement. In fast or systemic movement, the virus moves from an infection site to distant parts of the plant by using plant's own veins. For local movement from one cell to the another, viruses also use the channels that plant cells use to communicate with each other. These channels are called plasmodesmata which are microscopic channels connecting neighbouring plant cells. They are lined with proteins and are strictly controlled by the plants. Relative to the diameter of plasmodesmata, virus particles are huge. Almost all the plant viruses have the capacity to infect cells and only those that can progress from these initially infected cells and spread to other cells via plasmodesmata (PD), can establish a systemic infection. Complete virions or genomes are too large to diffuse freely in the cytoplasm, viruses use active intracellular transport, often along the ER/actin–myosin cytoskeleton, to reach PD, Viruses produce special proteins,

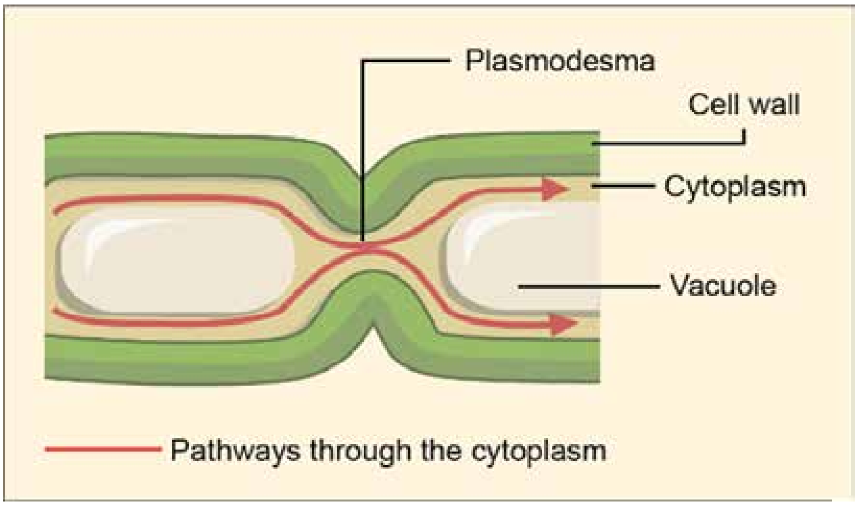

Fig. 1 Plasmodesmata

called movement proteins to overcome the plant's control of the plasmodesmata. PD are highly versatile nanochannels ensuring cytoplasmic and plasma-membrane continuity between adjacent cells. The small aperture allows small molecules to diffuse between cells and physically restricts the intercellular movement of macromolecules or macromolecular complexes such as virions and viral ribonucleoprotein complexes. A key step in this is the ability of viruses to encode one or more movement proteins (MPs) that interact with plasmodesmata (PD), increase their size exclusion limit (SEL), and facilitate the cell-to-cell transport of viral nucleic acids (DNA or RNA) or complete virions. Plant viruses use several different mechanisms to achieve this cell-to-cell movement.

Viral movement proteins can be classified into different types based on the characteristics and interaction with plasmodesmata. The first type is present in viruses like tobamovirus and triple gene block viruses. These viruses coming under potex virus, Carlavirus etc possess a set of three genes TGBp1, TFBp2, TGBp3 genes which are essential for the intercellular movement of the plant viruses and helps in overcoming cell wall barriers. TBGp1 act as helicase and RNA binding protein that helps the viral movement through plasmodesmata. TGBp2 and TGBp3 are integral to endoplasmic reticulum that form complexes with viruses through network of endoplasmic reticulum. Comoviruses and nepoviruses are typical examples of the second type. Their MPs assemble the tubules that transverse and modify the PD and guide virions to move to the adjacent cells. Another type is exhibited by viruses in the family Tombusviridae which utilize the products of two small partially

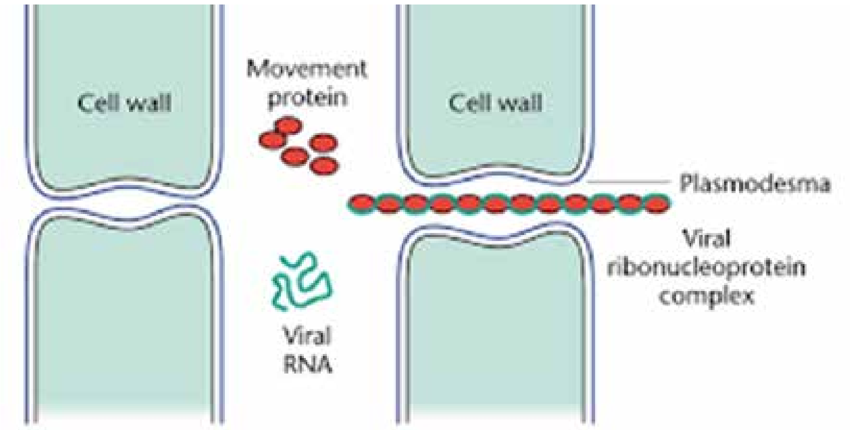

Fig. 2 Movement of virus through plasmodesmata

overlapping ORFs termed the double gene block (DGB) for cell-to-cell movement. The two viral proteins are named DGBp1 and DGBp2. DGBp1 is an RNA-binding protein, whereas DGBp2 is a small membrane protein.

The mechanism is that in some viruses the movement protein target plasmodesmata and increase its Size Extension Limit (SEL) and does not significantly modify the structure or form tubular structures and allows viral ribonucleoprotein to pass through plasmodesmata. In second type the movement proteins (MPs) form tubular structures that pass through and modify the plasmodesmata (PD), helping virions to move to neighbouring cells as in case of como and nepoviruses. In Potato Virus X RNA dependent RNA polymerase recruits vRNAs by an unknown mechanism and forms granular Viral Replication Complexes (VRCs) on the Endoplasmic Reticulum. These granular VRCs are highly mobile and are gradually clustered into large amorphous aggregates in the perinuclear area and the cell periphery as the infection progresses. In short the actual transport can be described under two types which include tubule less (non destructive) movement exhibited by many positive sense RNA viruses including Tobacco mosaic virus (TMV) and potyviruses in which the MPs bind viral RNA to form movement ribonucleoprotein (M complexes) that traffic through plasmodesmata whose permeability is transiently increased, often without gross structural damage and tubule guided (destructive) movement in which the viruses induce movement proteins that assemble hollow tubules spanning plasmodesmata. Entire virions move through these tubules from cell to cell. In both strategies, viruses frequently use ER/actin networks, plasmodesmata associated cell wall remodeling (e.g., callose breakdown), and host chaperones such as Hsp70 like proteins to translocate complexes through plasmodesmata.

The transport system of Tobacco mosaic virus (TMV) uses a single 30-kDa movement protein (MP). The first viral movement protein (MP) was identified from Tobacco mosaic virus in 1980s and is the most well-studied plant virus movement proteins. Later other types of movement proteins are also discovered from other viruses. It can bind RNA without sequence specificity and likely interacts with viral genomic RNA in the cell to form ribonucleoprotein (RNP) complexes, which enable cell-to-cell movement of the virus. TMV movement protein associates with the endoplasmic reticulum (ER) membranes and helps move viral replication complexes along the ER–actin network toward the plasmodesmata. TMV movement protein increases the plasmodesmata conductivity, or size exclusion limit (SEL), by one or more mechanisms, including remodeling the internal structure of the plasmodesmata channel, possibly by interacting with the plasmodesmata-resident protein SYT1, reducing the SEL decreasing callose depositions at the plasmodesmata neck regions by activating callose-degrading enzymes or by suppressing signalling that is activated in response to virus infection and leads to enhanced callose deposition. TMV movement protein is an endoplasmic reticulum associated protein that relocates to plasmodesmata possibly by interacting with synaptotagmin (SYTA) and can increase plasmodesmata size exclusion limits (SEL) to transport both viral and cellular RNAs to adjacent cells when located at the plasmodesmata. It is believed that TMV Viral Replication Complexes are transported by MPs to plasmodesmata since VRCs are located adjacent to plasmodesmata only in the presence of MP. Tobacco Mosaic Virus movement protein (MP) can form tubules on the surface of MP-expressing protoplasts whose structures resemble tubules formed by another class of MPs that transport viruses through plasmodesmata. In this mechanism, hollow MP tubules replace the plasmodesmata internal structure and extend into adjacent cells to facilitate virus movement. These types of movement proteins are found in many viruses and can be considered as universal

Genetic and cell biological evidence has shown that at least

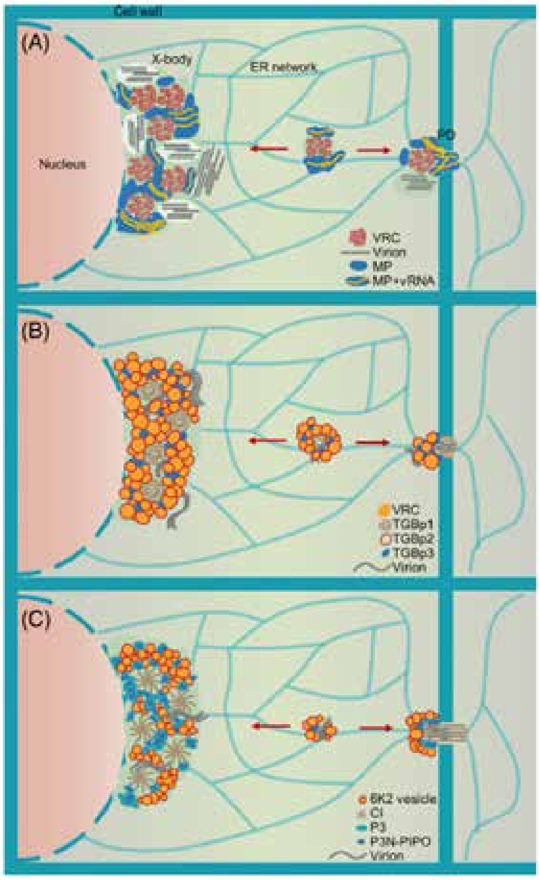

Fig.3 Illustrations of architecture and intracellular distribution of induced inclusions
A- TMV, B-PVX, C- TuMV (Wu and Cheng., 2020)

four viral proteins, namely, P3N-PIPO, cylindrical inclusion (CI), P3 and CP, are indispensable for potyviral cell-to-cell movement. Cylindrical inclusion protein localizes in both the nucleus and cytoplasm as cylindrical inclusion structures and accumulates at plasmodesmata as conical structures during virus infection. Cylindrical inclusion also interacts with the coat protein and direct CP to the plasmodesmata channels. Most of the studies suggest that most plant +ssRNA viruses anchor their VRCs at the entrance of plasmodesmata. One possibility is that viral genetic materials are transported as the form of intact VRCs, but generally believed that plant +ssRNA viruses move in the form of either ribonucleoproteins (RNPs) or virions.

All these studies conclude that viral cell-to-cell transport is considered to be a more complex process. Even tough selectivity may depend on specific binding of viral RNA by movement proteins; movement proteins have been shown to bind RNA non-specifically. Viral replication compartments are positioned close to plasmodesmata, allowing newly synthesized RNA to be directly transported to the plasmodesmata channels by movement proteins. A certain degree of selectivity may arise from specific interactions between movement proteins and viral replication proteins, which help to direct the replicative compartments toward plasmodesmata. Cell-to-cell spread of viruses in plants is a highly coordinated process that enables viruses to move efficiently through plasmodesmata and establish infection. Host factors and cytoskeletal elements also play important roles in guiding and regulating viral movement. Overall, successful cell-to-cell spread is essential for systemic infection and directly influences the severity and progression of plant viral diseases.

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Entomopathogenic Nematodes

ARUN CHANDRAN R P

Introduction

Beneficial nematodes are friendly organisms belonging to the nematode group that are capable of destroying insect pests attacking crops. They are known as Entomopathogenic Nematodes (EPNs). Nematodes belonging to the genera *Steinernema* and *Heterorhabditis* are mainly used for insect pest management. When these beneficial nematodes enter the insect body, the symbiotic bacteria living inside them kill the insect within 24 to 48 hours.

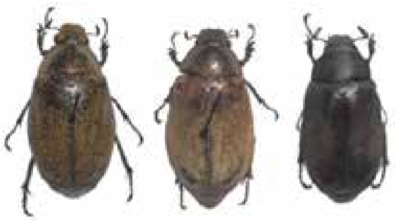
Beneficial nematodes are effective against pests such as root grubs in coconut and arecanut, red palm weevil, cashew stem borer, banana pseudo stem borer, white grubs, pumpkin beetle in cucurbit crops, and fruit borer in tomato. They are available in different formulations such as wax moth larval cadavers inoculated with beneficial nematodes (cadavers),EPN solution, and EPN granules.

Methods of application

Beneficial nematodes require moisture to move, locate, and destroy insect pests. Therefore, it is essential to maintain adequate soil moisture at the time of application. The recommended application methods for different pests are given below.

Root grub in coconut/ arecanut

Mix 150 ml of beneficial nematode solution in 10 liters of water and apply it to the basin of the palm. Alternatively,10 g of beneficial nematode granules can



be mixed in 1 liter of water and applied to the basin. Root grubs can also be controlled using nematode-infected cadavers. Apply four cadavers per palm, placing them on all four sides of the basin at a depth of 5–6 cm below the soil surface.

Banana pseudo stem borer

Place one cadaver each in the four innermost leaf axils of the banana plant. As an alternative to cadavers, mix 150 ml of beneficial nematode solution in 5 liters of water and pour it into the four innermost leaf axils.

Management of banana pseudo stem borer

Infestation of the banana pseudostem borer is mainly observed about three and a half months after planting. The pest

can be very effectively controlled through organic methods by using entomopathogenic nematodes, beneficial microorganisms such as Beauveria, and botanical insecticides like neem seed kernel powder, in an integrated manner.

The Krishi Vigyan Kendra (KVK) has successfully demonstrated this integrated management approach in farmers' fields through frontline demonstrations. The methods followed in these successful demonstrations are described below.

Method of Application

1. In the fourth month after planting, apply 50 g of neem seed kernel powder per banana plant by placing it in the four innermost leaf axils.

2. From the fourth month onwards, use Beauveria-treated pseudostem traps at the rate of one trap for every 40 banana plants. Replace the traps after 20 days.

3. In the fifth month after planting, place one cadaver each in the four innermost leaf axils of the banana plant.

   As an alternative to cadavers, mix 150 ml of beneficial nematode solution in 5 liters of water and pour it into the leaf axils.

4. In the sixth month after planting, mix 20 g of Beauveria in 1 liter of water and spray it on the leaf axils and pseudostem of the banana plant.

By following these control measures, the infestation of banana pseudostem borer can be reduced by about 90–95%.

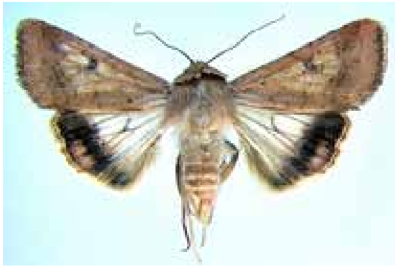
Banana rhizome weevil

Apply four cadavers per plant at the time of planting, and again two months and five months after planting. Place the cadavers on the four sides of the basin

at a depth of 5–6 cm below the soil surface. As an alternative to cadavers, mix 150 ml of beneficial nematode solution in 10 litres of water and apply it to the basin.

Pumpkin beetle in cucurbit crops

Within one week of planting, apply four cadavers per plant on the four sides of the basin at a depth of 5–6 cm below the



soil surface. If necessary, repeat the application after 20 days. As an alternative to cadavers, mix 150 ml of beneficial nematode solution in 10 litres of water and apply it to the basin.

Cashew stem borer / Red palm weevil in coconut

Mix 150 ml of beneficial

nematode solution in 10 litres of water and pour it through the holes in the stem/trunk. If pest infestation is noticed at the base of the plant, the beneficial nematode solution can also be applied to the basin.

Fruit borer in tomato

Mix 150 ml of beneficial nematode solution in 10 litres of water, or 10 g of beneficial

nematode granules in 1 litre of water, and spray on the foliage.

Beneficial nematode formulations such as EPN solution and cadavers, which enable highly effective organic control of insect pests attacking crops, are available at the Krishi Vigyan Kendra (KVK).

Conclusion

In summary, Entomopathogenic Nematodes (EPNs) represent a highly effective and eco-friendly biological control agent for managing devastating crop pests. By leveraging the symbiotic relationship between nematodes and bacteria, farmers can eliminate pests like root grubs and banana pseudo stem borers within a rapid 24 to 48-hour window.

The success of this method relies on moisture-rich soil and precise application techniques—whether through EPN solutions, granules, or infected cadavers. When used as part of an integrated pest management strategy alongside other organic tools like Beauveria and neem, beneficial nematodes provide a sustainable alternative to chemical insecticides, ensuring both crop health and environmental safety.■

Millets
The Super Foods

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In our day-to-day life we mainly depend on cereals for meeting our energy requirements. Nearly 60% of this is met from cereal grains including rice, wheat, maize (main cereals) sorghum, bajra, Ragi (major millets) and other minor/small millets. After Green Revolution, there is a drastic decline in area, production and dietary use of millets.

A time has come where top priority is given for quality and nutritious food. The issues of climate change are a challenge to the agricultural sector. Now we should think about the climate resilient crops to tackle the situation. In this context comes the importance of the small seeded millets which are climate resilient, less managed, drought resistant, even referred to as "pest free crops" and will be ready for harvest in a short span of time.

The production of millets has reached about 18.01 million metric tonnes from 12.86 million hectares in 2024-25 (MoA & FW, 2025) in India by the Government interventions for the promotion of millet cultivation in the country with Rajasthan, Karnataka and Gujarat being the lead producers and contributing 9.95% to the total food grain basket. The Department of Agriculture and Farmers Welfare (DA & FW) is implementing a Sub-Mission on Nutri-Cereals (Millets) under National Food Security Mission (NFSM) to enhance area, production & productivity of millets. Considering the nutritional value of the millets, the Government has notified millets as Nutri-cereals in April, 2018. The Millets are a rich source of Protein, Fibre, Minerals, Iron, Calcium and have a low glycaemic index. The important nutrients present in millets include resistant starch, oligosaccharides, lipids, antioxidants such as phenolic acids, avenanthramides, flavonoids, lignans and phytosterols which are believed to be responsible for many health benefits (Miller, 2001; Edge et al., 2005).

With the United Nations declaring 2023 as the International Year of Millets, they are back as a super food. Sorghum (Sorghum bicolor), Pearl millet/Bajra (Pennisetum glaucum), Finger millet/ragi (Eleucine corocana), Little millet (Panicum sumatrense), Kodo millet (Paspalam scrobiculatum), Foxtail millet (Setaria italica), Barnyard millet (Echinocloa frumentacea), Proso millet/ common millet (Panicum miliaceum) are the main millets that are grown as rain-fed crops. All the millets are members of the grass family Poaceae.

Sorghum (Sorghum bicolor)-Manicholam

It is the world's fifth most among the cultivated cereals. It is also called Great millet or Indian millet. The crop is valued mainly in the hot and arid regions for

its resistance to drought. Hence referred to as "Camel crop" and a climate smart crop. It is widely used as food, feed, fibre and as a bio-energy crop. Sweet sorghum biomass is used for bio-ethanol production. Sorghum malt is used for the preparation of non-alcoholic beverages and weaning foods. Its flour can be mixed with wheat flour to produce many baked products.

It can thrive on marginal soils with tolerance to salinity and alkalinity to certain extent. In Kerala the crop is raised in two seasons- May-August (rainfed) and January- April (irrigated). Seed rate is 6 kg/acre. Normally line sowing or dibbling is practised. Spacing adopted is 45 cm x 15 cm. Most of the high yielding varieties and hybrids take about 95-115 days to mature. Eighty percent of grains turn white/ straw coloured during this time. Average grain yield is 2500 kg/ha.

Pearl millet/ Bajra (Pennisetum glaucum)- Kambum

It is coarse grain millet widely cultivated in arid regions commonly called poor man's staple crop. It's a climate resilient nutri-cereal and has got very high photosynthetic efficiency with an excellent productivity. It is nutritionally superior and rich in micronutrients which can tackle the problems of malnutrition. It is also used as a feed and fodder for livestock. The crop can be cultivated both as rainfed (June-July and September-October) and irrigated (March -April). Seed rate is 12 kg/ha with a recommended spacing of 45 cm x 15 cm. Harvest the crop at 85-95 DAS when the moisture content of grains is about 20 percent, by cutting at the base or by removing ear heads. Then the ear heads are dried for 2-3 days followed by threshing. An average grain yield of 1200-1500 kg/ha is obtained.

Finger millet/ ragi (Eleucine corocana)- Koovaragu

It is one of the most nutritive and healthy millets. It is commonly referred to as finger millet. It has got tremendous health benefits too. Utilized in the pregnancy diet, as a common baby food and also for old-age people and patients. It has a high protein content, rich source of minerals (100 gms of Ragi contain 350 mg calcium and 3.9 mg iron), got antimicrobial, anti-oxidant activity and prevents cardio-vascular problems. Ragi has best quality protein along with the presence of essential amino acids, Vitamin-A, Vitamin-B and phosphorus (Gopalan et al., 2004). The crop has an inherent mechanism for utilizing available soil nitrogen efficiently and external nitrogen supplementation can be limited hence it can be grown under low nitrogen soils. Rejuvenation capacity of finger millet after the stress period is more as compared to other millets. As a direct sown crop, seed rate is 5 kg/ha, with a spacing of 25 cm x 15 cm. Harvesting will be done in 80-120 days, when the ear head turns to yellowish brown. Dry and thresh it.

Barnyard millet (Echinocloa frumentacea) -Kuthiravaali

It is one of the ancient millet crops which is widely cultivated in Asia. It is both used for human consumption and also as cattle feed. Barnyard millet is a short duration crop that can grow in adverse environmental conditions with almost no input and can withstand various biotic and abiotic stresses.

Besides these agronomic advantages, it has got very high nutritive value (as a rich source of protein, carbohydrates, fibre, and, most notably, micronutrients like iron (Fe) and zinc (Zn)) and has numerous health benefits. Lack of awareness about the crop makes it still an under-utilized crop. It is grown mainly during June-July and September-October as a rainfed crop. A seed rate of 8-10 kg/ha is needed with a spacing of 25 cm x 10 cm. Harvesting can be done when the grains change to brown colour. Seeds are separated by Threshing and Winnowing. Average yield is about 400-600 kg/ha.

Kodo millet (Paspalam scrobiculatum)- Varagu

Kodo millet is a drought tolerant crop with a crop duration of 90 days. It is a hardy crop that thrives well under areas receiving unpredictable rainfall conditions.

It prefers loamy fertile soils with high organic matter. The seeds are sown before the onset of monsoon during June-July or September-October with a seed-rate of 10 kg/ha under line sowing at a spacing of 25 cm x 10 cm. Kodo millet is harvested by cutting the stalk of the grass and allowing it to dry in the sun for two days. It is one of the toughest grains to de-husk. Approximate grain yield of 1200-1500 kg/ha is obtained.

Foxtail millet (Setaria italica)- Thina

It is the second most widely planted millet crop in India. It is fairly tolerant to drought, but cannot withstand water-logging. Due to its quick growth, it can be grown as a short-term catch crop. Grains are a rich source of Vitamin B12, which helps to maintain a healthy heart, good skin and hair growth. It is a general source of vital nutrients which can strengthen muscles and bones. Grains are also considered as a rich source of

proteins (9.7 gm), dietary fibres, carbohydrates, calcium and iron. It requires moderately fertile and well drained soils. Seed rate is 8-10 kg/ha for line sowing. Normally planted with a spacing of 25 cm x 10 cm at a depth of 2-3 cm. It is mainly grown as a rainfed crop. It matures in 80-90 days. Grain yield of 20-25 quintals is obtained.

Little millet (Panicum sumatrense/ Panicum miliare)- Chaama

It's a minor millet known for several health benefits; its grains are smaller in size than compared with the common millet. The grains are round and smooth. The crop can tolerate both

drought and water logging. Due to its earliness and resistance to drought, it is considered as a reliable catch crop. It's a wonderful millet suitable for all age groups and has a significant role in providing nutraceutical components such as phenols, tannins and phytates along with other nutrients. Deep, loamy and fertile soils rich in organic matter are preferred for its cultivation and can even withstand waterlogging. It is mainly grown as a rainfed crop during June-July or September October with a seed rate of 8-10 kg/ha at a spacing of 25 cm x 10 cm. Crop will be ready for harvesting in 65-75 days. Grain yield of 12-15 quintals is obtained.

Proso millet/common millet (Panicum miliaceum)- Panivaragu

It's an important and short duration minor millet specially adapted to high altitudes and tropics. The common millet has the lowest water requirement among the millets. It can very

well evade drought due to its early maturity. Seed rate of 10 kg/ha is recommended. Sown in a spacing of 25 cm x 10 cm. The ideal time for raising the crop is from June-July. As a summer crop, it can be raised from February- March. The crop can be harvested when two-thirds of the grains are ripe (70-80 days). Ripening is not so uniform in proso millet. Delay in harvesting will result in shattering of the grains. Grain yield of 1500 kg/ha can be obtained under irrigated conditions and 600-700 kg/ha in drylands.

Uses and benefits of millet cultivation

- Grains can be used as food and feed
- Stover used as fodder
- Millets will enrich agro-biodiversity
- Fibrous roots aid in erosion control
- Good candidates for food and nutritional security
- Millets has the power for carbon sequestration.

Major share of millet cultivation in Kerala has been concentrated in Attappady, among the tribal communities. Now a time has come, to value these climate resilient, smart and under-utilized millets. The area under millets has been expanding slowly to other districts also.

Millets truly deserve their title as "superfoods" due to their rich nutritional profile, resilience, and health benefits. They are packed with fiber, vitamins, minerals, and antioxidants, making them excellent for managing lifestyle diseases like diabetes, obesity, and heart conditions. Beyond health, millets are environmentally sustainable, requiring less water and thriving in harsh climates, which makes them vital for future food security. Promoting millets in daily diets not only supports better health but also encourages sustainable agriculture and supports farmers. Overall, millets represent a smart, nutritious, and eco-friendly choice for a healthier future.

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Building Agricultural Resilience

Navigating the challenges of climate change

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Abstract

Climate change is posing a serious threat to global agriculture, affecting crop production, livestock, fisheries and overall food security. Rising temperatures, erratic rainfall and extreme weather events are leading to significant yield loss in major food crops and leading to economic instability among farmers. Climate-resilient agriculture has emerged as a sustainable approach to address these challenges by enhancing adaptive capacity, improving productivity and reducing greenhouse gas emissions. This article highlights the impact of climate change on agriculture and discusses key adaptation strategies, extension services and institutional support systems necessary for building resilience in agriculture.

Keywords: Climate change, resilience, adaptation and mitigation

Introduction

Agriculture is a vital sector in India providing livelihood support to a large (800 million people) section of population and ensuring food security. It is highly dependent on climatic factors such as temperature, rainfall, humidity and seasonal patterns. In recent years climate change has emerged as a major challenge affecting agricultural systems. Rising temperatures, irregular rainfall, frequent droughts, floods and extreme weather events are increasingly observed. These changes reduce crop productivity and increase the vulnerability of farmers especially small and marginal farmers. Climate change also affects soil health, scarcity of water resources, increasing incidence of pest and disease and also affects livestock productivity. Higher temperature lead to heat stress while erratic rainfall causes both water scarcity and flooding. India is highly vulnerable to climate variability particularly in dryland regions like Karnataka. Farmers are already experiencing crop failures declining groundwater levels and increased pest outbreaks. In this situation building agricultural resilience is essential. Climate-resilient agriculture helps farming systems to withstand adapt to and recover from climate stress. Therefore, adoption of climate-smart practices and strengthening extension services are necessary for sustainable agriculture. (Rajesh et al.,2024)

Challenges of climate change

To overcome the challenges mentioned in Figure 1, it is essential to build climate resilience across different sectors. Climate resilience is not limited to crop production alone but also involves a comprehensive approach including agriculture, horticulture, livestock, fishery, forestry and storage and processing systems. Therefore, an integrated approach involving all these sectors is necessary to effectively respond to climate change and ensure sustainable agricultural development. (Priya et al., 2025)

1. Strategies for climate change adaptation

- Integrated Farming System (IFS)

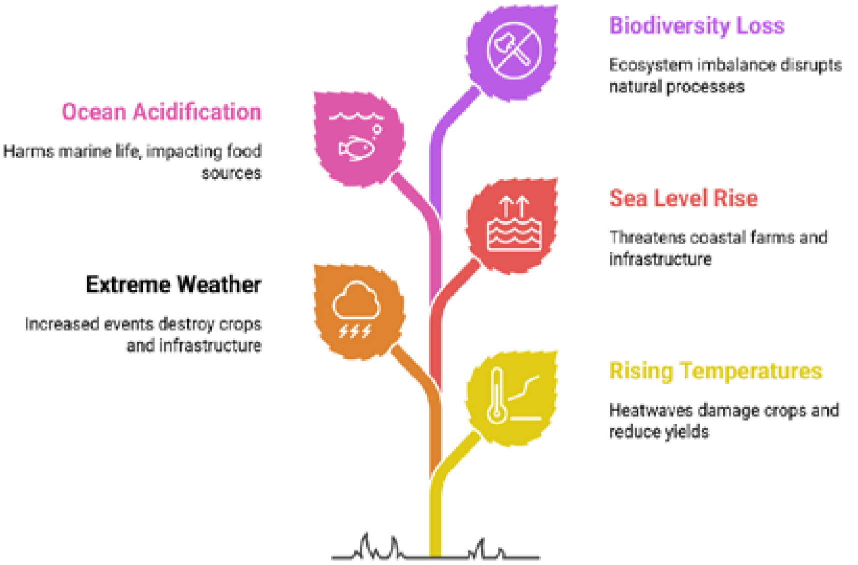

Figure 1. Challenges of climate change

    - Combines crops, livestock and other subsidiary enterprises
    - Improves resource use efficiency
    - Enhances farm income and sustainability
- Zero Tillage
    - Minimizes soil disturbance
    - Conserves soil moisture
    - Reduces soil erosion and carbon loss
- Weather Forecasting and Dissemination
    - Provides timely weather information
    - Helps in decision making in major agricultural operations like, sowing, irrigation, harvesting and marketing
    - Reduces risk from extreme weather events
- Water Saving Technologies
    - Promotes drip and sprinkler irrigation
    - Efficient use of available water resources
    - Supports crop growth during water scarcity

2.Climate change mitigation strategies in horticulture

Climate change is increasingly affecting horticultural production through erratic weather, water scarcity and rising pest and disease incidences. To overcome these challenges, adopting climate-resilient strategies is essential for sustaining productivity and farm income. The following Figure 2 outlines the major approaches that support resilience and long-term sustainability in horticulture. (Dutta et al.,2023)

3. Strategies for climate resilient livestock

1. Shelter Management

- Protects animals from high and low temperatures
- Reduces effects of humidity, solar radiation, wind and rain
- Provides a comfortable environment for livestock

2. Water Management

- Ensures availability of clean drinking water
- Rainwater harvesting and storage systems
- Maintains productivity during dry periods

3. Feeding Management

- Provides balanced nutrition for animals
- Addresses feed and fodder scarcity in drylands
- Improves productivity and health

4. Grazing Management

- Rotational grazing practices
- Maintains natural vegetation
- Reduces environmental stress

5. Health Monitoring

- Regular monitoring of animal health
- Early disease detection
- Timely veterinary care to reduce losses

4. Adaptation Measures for Climate Resilient Fisheries

Climate change is significantly affecting fisheries by altering water temperature, marine ecosystems and fish availability. To reduce these impacts

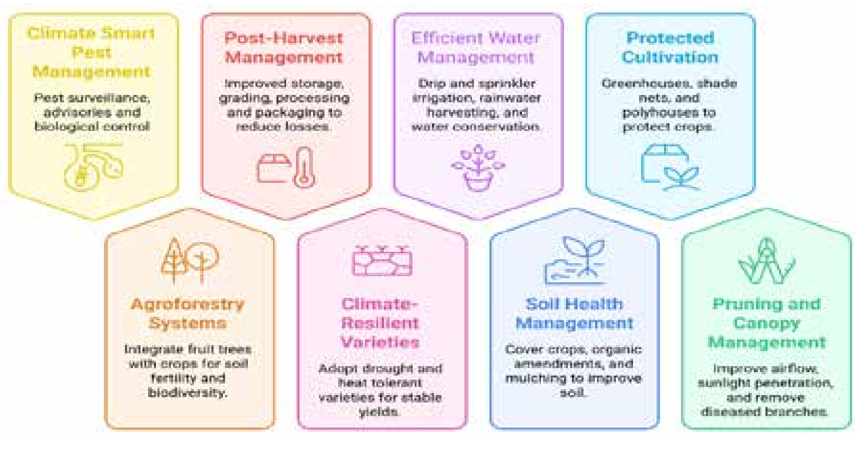

Figure 2. Key strategies for climate resilient horticulture

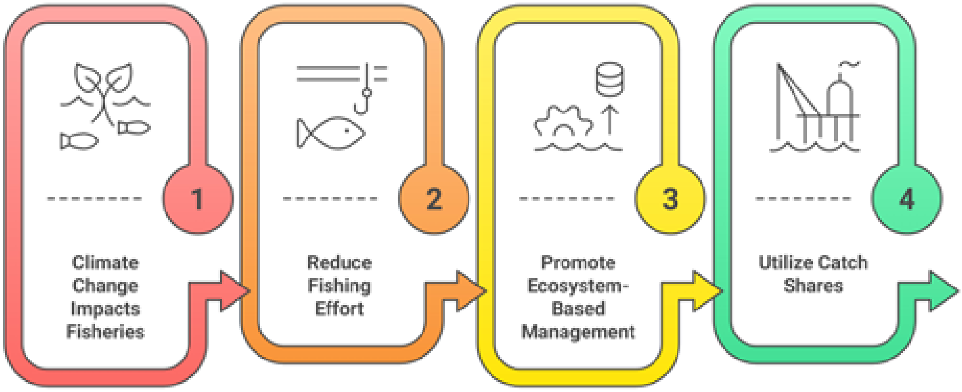

Figure 4. Adaptation measures for climate resilient fisheries

and ensure sustainable fish production, several adaptation measures can be adopted as shown in Figure 3.

5. Climate resilient storage system

Climate change has a significant impact on post-harvest management by increasing risks such as heat stress, humidity, pests and extreme weather events. These factors lead to storage losses, deterioration in quality and economic losses for farmers. Therefore, adopting climate-resilient storage systems is essential to protect agricultural produce, maintain quality and reduce post-harvest losses. Proper storage practices help ensure food security and improve farmers' income.

Extension services to build climate resilience

1.Plant Clinics

Diagnose and provide solutions for crop related problems

2. Farmer Field School (FFS)

Practical learning and skill development

3. Village Knowledge Center

Access to agricultural information and technologies

4. ICT Supported Network

Dissemination of real-time information and advisories

5. Rural Advisory Services

Provide location-specific guidance to farmers

Conclusion

Climate change is a major challenge such as rising temperatures, erratic rainfall, extreme weather events and increasing pest and disease incidence affecting all sectors of agriculture including crops, horticulture, livestock, fisheries, forestry and post-harvest systems. As a consequence, it is threatening productivity, livelihoods and food security. An integrated and holistic approach that combines adaptation and mitigation strategies across all agricultural sectors is essential for ensuring long-term sustainability. Therefore, building agricultural resilience is not just a necessity but a key strategy to ensure food security, environmental sustainability and improved livelihoods for present and future generations.

Characteristic	Prevention	Monitoring	Treatment
Extreme Heat	Cold storage, preserving techniques	ICT sensors	Prevent post-harvest losses
Flooding and Wind	Pallets, distance, hygiene	Climate-resilient infrastructure	Select appropriate location
Pests and Diseases	Jute bags, hermetic bags	Early warning systems	Prevent damage from pests
Relative Humidity	Dehumidifiers, ventilation	Roof ventilators, wall vents	Vapor heat, hot water

Figure 5. Climate resilient storage system

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Wolffia arrhiza
The Tiny Green Powerhouse Redefining Future Food

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Introduction

In a world grappling with population growth, climate change, and the urgent need for sustainable nutrition, scientists and food experts are constantly searching for innovative food sources. One such discovery is Wolffia arrhiza, a tiny, rootless aquatic plant that is making waves in the field of future foods. Commonly known as "watermeal" or "Mankai," Wolffia is the smallest flowering plant on Earth—so small that a handful of grains can float unnoticed on the surface of a pond. But despite its miniature size, it carries an enormous nutritional punch.

Packed with high-quality protein, essential amino acids, vitamins, minerals, and antioxidants, Wolffia arrhiza is being hailed as a natural, plant-based alternative to animal protein. Unlike soybeans or lentils, it grows directly on water, requiring minimal land and almost no fertilizers. Remarkably fast-growing—it can double its biomass in just 2–3 days—this humble green speck offers a sustainable solution to food security and environmental challenges. Already consumed traditionally in parts of Southeast Asia, it is now attracting global attention as a "superfood of the future," with applications ranging from human diets to livestock and aquaculture feed. Wolffia arrhiza is more than just a curious pond plant—it may soon become a staple on our plates, redefining the way we think about green, sustainable nutrition.


Image of Wolffia arrhiza, in the pond

Nutrition and Health Benefits of Wolffia arrhiza

For humans, Wolffia arrhiza is a nutritional powerhouse. Despite being the tiniest flowering plant on Earth, it contains nearly 40–45% high-quality protein by dry weight—comparable to soybeans and higher than many cereals. Unlike many plant proteins, it provides all essential amino acids, making it a complete protein source similar to animal-based foods. It is also rich in vitamins such as B12, A precursors, and C, and essential minerals like iron, calcium, magnesium, and zinc. This nutrient-dense composition supports muscle growth, immunity, and digestive health. Its high protein, fiber, and antioxidant content help protect against oxidative stress, improve gut microbiota, prevent anemia, and maintain cardiovascular well-being. With a low glycemic index, it is suitable for diabetic diets and provides a balanced, nutrient-rich addition to vegetarian, vegan, and general diets. Recent studies even suggest that regular consumption of Wolffia may aid in weight management and cardiovascular health, solidifying its status as a true superfood for human nutrition.

For animals, Wolffia arrhiza offers an equally remarkable solution as a sustainable feed option. Its high protein content, digestibility, and rich mineral profile support growth, immunity, and productivity in livestock, poultry, and fish. Its rapid growth, easy cultivation, and minimal resource requirements make it an affordable, eco-friendly alternative to conventional feeds like soybean meal. By providing high-quality nutrition at a lower cost, Wolffia not only enhances animal health and performance but also contributes to more sustainable and efficient food systems, bridging the gap between nutrition, agriculture, and environmental conservation.

Global Criteria and Research Status of Wolffia arrhiza

Several countries have advanced in Wolffia research and commercialization. Israel pioneered large-scale cultivation and food-grade processing through companies like Hinoman Ltd., which markets Wolffia globosa (branded as "Mankai") as a plant-based protein ingredient used in beverages, nutrition bars, and ready-to-eat meals. Japan and Thailand have a long tradition of consuming Wolffia species locally known as "Khai-nam," and ongoing research there focuses on optimizing pond-based and bioreactor cultivation systems for food and feed applications. In Europe, Wolffia is being explored under controlled hydroponic and aquaponic setups to meet the increasing demand for sustainable protein alternatives. The Netherlands, for instance, has evaluated Wolffia in closed-loop aquaponic systems for both nutrient recycling and protein production, while Germany and Switzerland have studied its role in wastewater bioremediation and functional food development.

In the global research community, Wolffia is also being recognized for its dual-purpose potential—as a high-protein food source and an environmental biofilter capable of removing nitrogen, phosphorus, and heavy metals from wastewater. This dual benefit enhances its appeal in sustainable agriculture and urban farming systems. The plant's suitability for vertical farming, aquaponics, and space-farming models has led even NASA and space-agriculture researchers to consider it for closed ecological life-support systems due to its rapid growth and oxygen release.

Good Agricultural Practices for cultivation

For successful cultivation, Wolffia arrhiza requires a warm tropical to subtropical climate, ideally maintaining water temperatures between 25°C to 35°C. It thrives in non-saline, still or slow-moving freshwater with a pH range of 6.5 to 8.0. Adequate sunlight, typically around 10,000 to 15,000 lux, is essential for efficient photosynthesis and biomass accumulation. The nutrient medium used should be well-balanced in essential macronutrients such as nitrogen, phosphorus, and potassium, along with trace micronutrients similar to those used in hydroponic systems.

Nutrient Mediums for Growing Wolffia arrhiza

Synthetic Nutrient Medium

Under controlled or research conditions, Wolffia arrhiza is commonly grown using Hoagland's nutrient solution or its modified versions. This synthetic medium supplies all essential nutrients—nitrogen, phosphorus, potassium, calcium, magnesium, and trace elements—necessary for rapid growth and high protein content. The solution's pH is maintained between 6.5 and 7.5, and electrical conductivity (EC) around 0.5–1.0 mS/cm ensures efficient nutrient uptake. Regular replacement of the solution keeps the plants healthy and prevents nutrient depletion or algal growth.

Organic Nutrient Medium

For sustainable and eco-friendly cultivation, Wolffia can be grown in organic nutrient media prepared from natural sources such as cow dung slurry, compost tea, vermiwash, or poultry manure extract. These organic options provide balanced nutrients along with beneficial microorganisms that improve water quality and plant vigor. Dilution of these organic media (1:10 to 1:20 ratio with clean water) prevents excessive nutrient buildup and supports stable growth comparable to synthetic solutions.

Farm-Level Practical Approach

At the farm level, farmers can cultivate Wolffia arrhiza in lined ponds or tanks using diluted organic manures available locally. Nutrient-rich fish pond water or biogas slurry filtrate can also serve as a low-cost medium. Maintaining shallow water depth (5–15 cm), periodic aeration, and replenishing nutrients every few days are essential for continuous growth. With simple management and locally available resources, farmers can produce a nutrient-dense, fast-growing Wolffia crop suitable for food, feed, and income generation.

Propagation

Propagation of Wolffia arrhiza is entirely vegetative, as the plant reproduces through clonal budding. Under favorable environmental conditions, each plantlet divides every one to three days, leading to exponential growth. Cultivation is generally initiated by introducing approximately 50 to 100 grams of fresh Wolffia biomass per square meter of the water surface. A shallow water depth of 5 to 15 centimeters is maintained to ensure proper nutrient absorption and easy harvesting.

Pest and Disease Management

Wolffia is a resilient little plant—rarely troubled by pests—but like all aquatic crops, it appreciates clean water and good aeration." Wolffia arrhiza is largely pest-free, though occasional algal growth or fungal contamination may occur in stagnant water systems. Such issues can be managed by maintaining good water quality, regular aeration, and biological control measures, such as the application of Trichoderma species or neem-based formulations. Over-fertilization should be avoided to prevent eutrophication and algal competition.

Harvesting

Harvesting of Wolffia arrhiza can be done every three to five days, as the crop regenerates rapidly. The floating biomass is usually collected using fine mesh nets. Under optimal conditions, the yield can reach up to 10 to 15 tons of fresh biomass per hectare per month. Post-harvest, the material should be dried at temperatures below 45°C to retain its nutritional integrity, especially proteins and vitamins. The dried product can be converted into powder form and incorporated into food products, animal feed, or nutraceutical formulations.

Future Prospects and Challenges in India

Despite its promise, large-scale Wolffia cultivation still faces challenges like, Affordable mechanized harvesting is needed for small and marginal farmers to make Wolffia cultivation viable. Promoting Wolffia's high-protein content and environmental benefits can boost adoption in Indian diets. Standardized testing and quality guidelines are essential for domestic and export markets. Wolffia thrives in waterlogged areas, making it ideal for flood-prone regions. It can be cultivated alongside paddy or in rice-fish systems, improving land and water productivity. Its fast growth helps in nutrient absorption, potentially improving the water quality of paddy fields. With research and government support, India can emerge as a leading producer of sustainable Wolffia-based foods.

Conclusion

Unlike rice or wheat, Wolffia requires no soil, less water, and grows 20 times faster. Compared to soybean, it delivers similar protein quality but with lower carbon and water footprints. In summary, the global criteria that define Wolffia arrhiza as a "future food" are its nutritional richness, ecological sustainability, rapid harvest cycle, and adaptability to controlled environments. From Asian traditional diets to European superfood shelves, Wolffia is steadily transitioning from a local aquatic plant to a global agricultural innovation—bridging science, nutrition, and sustainability. Tiny yet mighty, Wolffia arrhiza reminds us that the future of food may not lie in vast farmlands but in the quiet ripples of a pond. ■

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