# IOT Enabled:Air Flow Controlled Pollination System in Vertical Farming


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***Abstract*—The research paper focuses on air-controlled pollination which introduces an innovative approach to address the crop yield challenge and importance of pollination in vertical farming. By accurately manipulating air currents, this method replicates the natural process of wind pollination by predicting from the selected parameters. The study analyzes various parameters like air velocity and direction and synchronizes them with plant development stages. This ensures precise and efficient pollination within the vertical farm environment. The paper demonstrates the potential of this technology to revolutionize vertical farming practices by enhancing crop yields, promoting biodiversity, and contributing significantly to sustainability in agriculture. It not only provides a solution for a pressing challenge faced by vertical farmers but also represents a remarkable amalgamation of advanced technology and ecological principles, marking significant progress in sustainable agriculture.**



***Keywords*-**IOT, Vertical Farming, sensors, crop yield, pollination


## I. Introduction

A highly efficient and sustainable method of food production, vertical farming involves growing plants indoors in layers using LED lighting and controlled growth and nutrient systems. Most of the farm looks like a warehouse full of large shelves. By carefully controlling the growth environment, the normal growth period of 3-4 days can be extended to 13-14 days. Crop yield in agriculture is increased by pollination, fertilizer, etc. Traditional outdoor farming relies on natural pollinators such as bees, butterflies and the wind to promote pollination. Certain plants such as grasses and many trees (such as oaks, pines, wheat, and maples) rely on the wind for pollination. These plants produce lightweight pollen grains that can be carried long distances by the wind. Without pollination, the yield of various crops can be severely limited, making it important to explore alternative methods. Controlled airflow helps spread pollen and increases the likelihood of successful fertilization. And higher efficiency An effective ventilation system provides good airflow and helps manage heat and humidity levels. Moisture accumulates as a result of transpiration in plants and evaporation in irrigation systems. This research paper examines the challenges facing vertical farming due to the lack of natural pollinators and reviews various artificial pollination methods including mechanical, robotic and biotechnological approaches. This research paper explores the integration of controlled air pollination technology as a solution to this challenge. This advanced approach seeks to mimic the complex fins of wind pollination within the confines of a vertical farm. Using the power of controlled airflow, this technology replicates the gentle caress of the breeze and the deliberate flight of pollinators, ensuring that pollen moves seamlessly from flower to flower. Parameters such as speed, direction of air flow are controlled when pollination is observed at the appropriate stage of the plant.

### A. Motivation

The integration of air-controlled pollination in vertical farming represents a revolutionary leap in agricultural science, fueled by a pressing need to redefine food production methodologies in the face of unprecedented challenges. Urbanization, climate change, and a burgeoning global population have intensified the demand for sustainable, efficient, and locally sourced agricultural practices. Traditional farming, while reliable, is constrained by space limitations, seasonal constraints, and environmental uncertainties. Vertical farming emerged as a beacon of hope, offering a solution to these challenges by cultivating crops in controlled indoor environments.This research lies aims in the imperative to bridge the gap between the controlled environments of vertical farming and the ecological processes crucial for crop pollination.

### B. Organisations

The remaining sections are organized as follows. Section II is a review of existing literature related to the topic of the study. Section III describes the study design, methodology, and proposed research objectives while Section IV gives the presentation and analysis of the study findings, including any trends or patterns observed and how they relate to the research questions. Finally, Section V presents the concluding remarks and discusses the prospective scope of the research work for the future.

## II. VERTICAL FARMING

### A. The rise of vertical farming

Vertical farming has received much attention in recent years due to its potential to transform agriculture, especially in urban areas.It allows farming to be done in vertically stacked heights, making it suitable for urban areas where the horizontal area is limited. Both the need for land and the restriction to rural areas were addressed through stand-alone agriculture.It allows agriculture to be practiced in densely populated urban areas, reducing the need for long distances by car on the snow. These methods provide controlled conditions for plants, allowing them to be grown all year round unaffected by outside weather.These methods grow plants in water without soil.Hydroponic uses chemical fertilizers in solutions form with roots dip in for internal use, aeroponics for growing in Limited internal water use by spraying the roots, periodic irrigation of roots and aquaponics support plant growth and fish production together, using fish waste as fertilizer for the plants. In addition, by combining smart sensors and artificial intelligence algorithms, these variables can be monitored and adjusted in real time to ensure optimal growing conditions and maximize productivity.

In addition, vertical farming facilitates the cultivation of a variety of crops, including exotic and special plants that may not grow in traditional outdoor environments. This diversity not only meets specific market needs, but also promotes agricultural biodiversity. By growing a variety of crops in vertically stacked systems, urban farmers can help preserve genetic diversity. This is essential for long-term food security and resilience to the effects of disease and climate change.

### B. Requirement of technology in Vertical Farming

There are several vertical farm equipment producer startups (e.g. Urban Crop Solution [**2**] or Infarm [**3**]) or companies who build up their own vertical farm to produce plants. They are mainly specialized on food production for given plants (like salad, cabbage, spinach). Such facilities work with special production equipment optimized and build up for this use only [**1**]. Requirements reflect the current state and future trajectory of the vertical farming industry:

- Reducing Fertilizer, Water Usage, and CO2 Emissions:
  In their current form, vertical farms are designed to use water and fertilizer more efficiently than conventional agriculture. Soilless and aeroponic systems reduce water use. Continuous improvements in nutrient distribution and water recycling technology will increase water and fertilizer efficiency. Additionally, integrating carbon capture and utilization systems can further reduce CO2 emissions.
- Increasing Irrigation and Water Reservoir Automation:
  Many vertical farms utilize automated irrigation systems to precisely control water delivery to plants.Automation will become more sophisticated, incorporating AI algorithms to optimize irrigation schedules based on plant needs, weather patterns, and overall farm efficiency.
- Reducing Growing Process Losses:
  Vertical farming minimizes losses due to pests, diseases, and adverse weather conditions, enhancing overall crop yield and quality. Advances in plant monitoring technologies and predictive analytics will further reduce losses by enabling early detection of issues and proactive intervention.
- Increasing Grow Box Energy Optimization:
  LED technology is widely used in vertical farming due to its energy efficiency and ability to provide specific lighting suitable for growing plants. Research in lighting technology will lead to more powerful LEDs and improved spectral composition. Internet of Things (IoT) systems will increase energy efficiency by allowing real-time monitoring and updating of light levels and the usage of light by the plants.
- Creating Sensing Capability for the Whole Plant Lifecycle:
  The factors such as light intensity, temperature, soil moisture is monitored using real time data and adjustments are made subsequently to ensure the smooth running of the system.[9] Sensors are deployed in vertical farms to monitor various parameters such as humidity, temperature, and nutrient levels.Sensor technologies will continue to evolve, providing a comprehensive understanding of plant physiology. This data will be integrated into AI systems, enabling precise control over growth factors and facilitating data-driven decision-making for optimal plant development.

### C. Increasing crop yield

- Implementing robots for tasks such as planting, harvesting, and maintenance, increasing efficiency and reducing labor requirements.Using sensors to monitor environmental factors such as temperature, humidity, light intensity, and nutrient levels.
- Precision control of nutrient delivery systems using automation, ensuring plants receive the right nutrients at the right time.
- Increasing carbon dioxide levels within the indoor environment enhance the photosynthesis, leading to faster growth and higher yields.Using renewable energy sources and energy-efficient technologies to power the vertical farming facility.

- Implementing water recycling systems to minimize water wastage and promote sustainability. Aeroponics is the type of vertical farming using very limited water, by spraying only the roots at particular intervals.
- Developing genetically modified crops that are adapted to indoor environments and have improved resistance to diseases and pests. Analyzing the collected data to optimize growing conditions and make informed decisions for crop management.
- Controlled pollination enables better crop yield in same variety of plant breeds. Ensuring that plants within the same species flower simultaneously results in increase the chances of successful pollination.The timing of pollen have to well understood to release from male flowers and position fans to coincide with this release, maximizing the chances of pollen transfer.Data is collected on plant growth, flowering patterns, and yield to evaluate the effectiveness of wind pollination efforts.Based on the data collected, the placement of fans are refined strategically , adjust environmental conditions, and experiment with different plant species to optimize the wind pollination technique for your specific vertical farming setup.

## III. METHODOLOGY

Stacked layer farming has various advantages. It offers an efficient utilization of space while reducing the dependency on arable land. Additionally, it allows for year-round crop cultivation due to controlled indoor environments. However, these indoor conditions can lead to limited crop yield. To address this issue and optimize crop production in vertical farming, different techniques and technologies are employed.

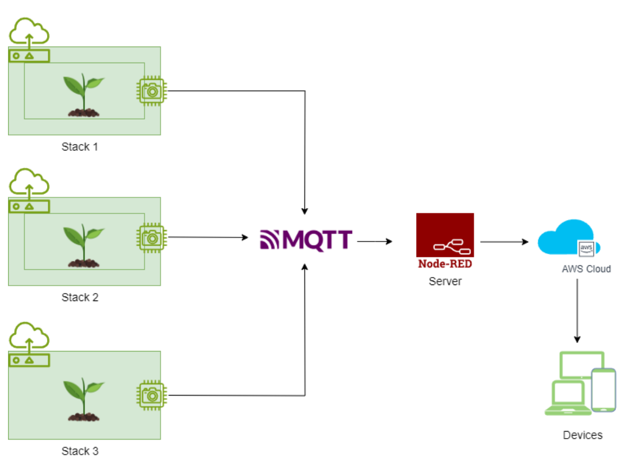


Fig. 1. Working of air flow controlled pollination system

1) Customized Spectrum:

LED lights can be adjusted to emit specific wavelengths of light, catering to the unique needs of plants at different stages of their lifecycle. By providing targeted light, these plants receive the optimal stimulus for growth.

1) Types of vertical systems:

- Hydroponics: Plants are nurtured in nutrient-rich solutions, eliminating the necessity of presence of soil and allowing precise control over their nutrient intake.[7] This method ensures that plants receive an ideal balance of essential elements.
- Aeroponics: Plants are suspended in air and gently misted with nutrient solutions.This is good replacement to the prevalant irrigation dependent farms. This promotes elevated oxygen levels and facilitates efficient absorption of nutrients, fostering vigorous plant development.
- Aquaponics: It is a sustainable farming method that combines aquaculture (fish farming) with hydroponics (soil less plant cultivation). The system works by using the waste produced by fish to provide nutrients to plants, which in turn clean the water for the fish[**11**].

1) Climate Control:

Temperature and humidity control play a crucial role in creating an optimal environment for plants to thrive. By carefully maintaining specific levels of temperature and humidity, we ensure that plants receive the ideal conditions Third-Person, Balanced Emotion, Neutral Formality,CO2 enrichment has been found to enhance photosynthesis and increase

1) Vertical Farming Structures:

Automated systems facilitate the movement of trays/racks containing plants, ensuring an even distribution of light and facilitating hassle free maintenance. Green Walls is a practice that involves growing plants vertically on surfaces such as walls, allowing for optimal utilization of space.

### *A. Sensing the growth of plants:*

Humidity, temperature and camera sensor are required for measuring both variables in VF installations[**4**].Visual images from the cameras help in getting a wide knowledge about the pollination stage. VF is introducing new technologies to face these challenges. Customized spectrum LED lighting ensures optimal energy use for photosynthesis. AI is being used for monitoring crop growth in VF increasing production, color images are used to monitor crop growth and pollination stage of the plant[**5**]. In addition, AI can predict plant behavior [**6**]. Regarding the use of sensors and IoT technologies, they can be used for controlling and increasing the efficiency of water use, as can be seen in Ref. [**7**].To analyze the data collected by sensors to understand plant growth patterns and make predictions about the optimal time for pollination, the data is collected into the Raspberry Pi and transferred to the cloud.Raspberry Pi has GPIO (General Purpose Input/Output) pins that can be used to connect various sensors such as temperature sensors, humidity sensors, motion detectors, light sensors.Sensors can be connected directly to these GPIO pins, or via protocols such as I2C, SPI, or UART, using additional hardware like breakout boards or sensor modules.Python scripts are written to interface with connected sensors and read data.

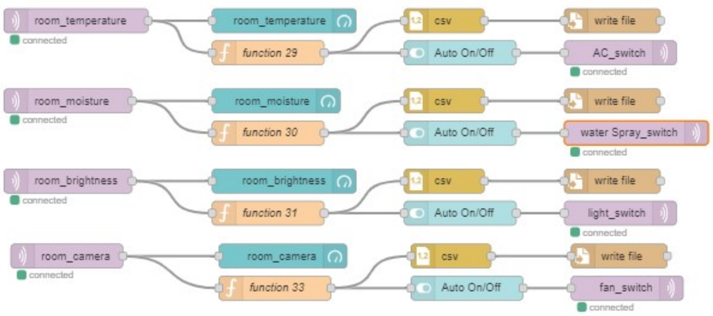


Fig. 2. Designed model of working of sensors

### B. Transfer and storage of data over cloud :

A cloud service provider such as AWS IoT or Microsoft Azure IoT is used to store and manage your IoT data.Cloud API Integration is done by Using the APIs provided by the cloud service to send data from Raspberry Pi to the cloud. This involves using protocol MQTT (Message Queuing Telemetry Transport) for data transmission. Cloud platforms enable remote monitoring of IoT devices from anywhere with an internet connection. This helps the users to access real-time data through web dashboards or mobile apps.These services allow users to send commands to IoT devices remotely, enabling control over connected devices.Databases like MySQL, PostgreSQL, or MongoDB are used to store sensor data in a structured manner enabling easy access and processing of the data.

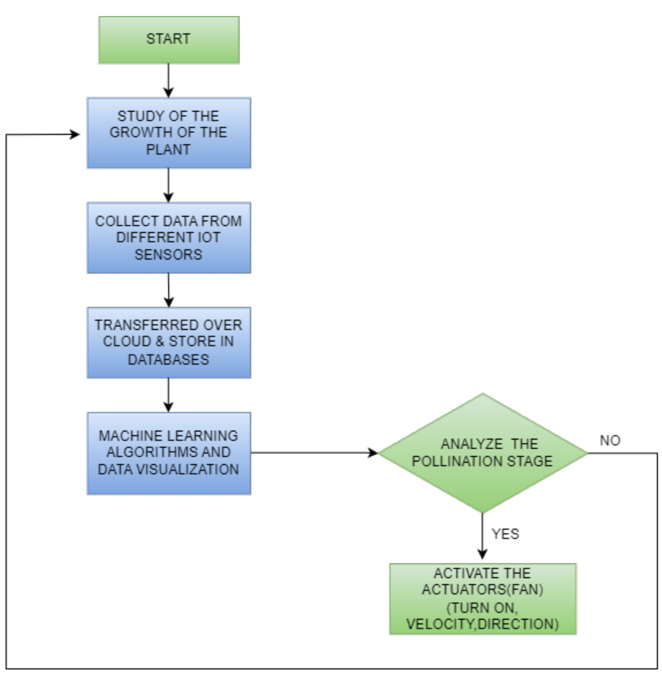


Fig. 3. Workflow of the proposed system

### C. Monitoring the growth and commanding the Actuators:

A web-based dashboard or mobile app is created that communicates with the cloud server to display real-time sensor data and allow users to monitor the IoT devices remotely. Machine learning algorithms are implemented to predict plant growth stages based on sensor data. These algorithms can then trigger automated air flow systems for pollination when the plants reach the right stage.

Temperature, humidity, and visual features are analyzed from the data based on some certain thresholds that correspond to different pollination stages. If light intensity is high, temperature is within a certain range, and humidity is moderate, and the flower's color has changed to a specific hue (indicating maturity), it might be in the pollination stage. If light intensity is low, temperature is too high or too low, and humidity is extremely low, it might indicate a different stage (e.g., pre-bloom or post-pollination). Visual data use image processing techniques to extract relevant features from the images, such as color, size, and shape of the flower. Machine learning algorithms are used to detect patterns and anomalies in the data, predict crop growth, and automate tasks.[**12**] Machine learning algorithms (such as decision trees, support vector machines, or neural networks) are used to train a model based on historical sensor data and labeled pollination stages.The pollination stage of the flower is predicted using the trained machine learning model. Control mechanisms are implemented in the dashboard, allowing users to send commands back to the Raspberry Pi for device control (e.g., turning on/off actuators based on sensor readings).

The commands control fans in the vertical production of airborne pollinators. It connects a relay module to the Raspberry Pi GPIO pins to connect the fans to the Raspberry Pi and programs the Raspberry Pi to control the fans based on specific conditions, ie. pollination stage of the plant. The relay module acts as a switch and is used to control high-power devices (such as fans) via a low-power microcontroller (such as the Raspberry Pi). Python scripts can be used that read pollination stage data from the visualization created and decide when to turn the fan on or off or to change the speed or direction.

**Algorithm 1:** Fan Control Algorithm

```
Input: Pollination stage data
Output: Fan state (ON or OFF)
Function ControlFan(pollinationStage):
    Data: pollinationStage (string)
    Result: Fan state
    If
        pollinationStage equals "wind"
    Turn fan ON;
    Print("Fan is ON for wind pollination stage.");
    else
        Turn fan OFF;
        Print("Fan is OFF.");
while true do
    Data: pollinationStage = getPollinationStage()
    ;
    ControlFan(pollinationStage);
```

## IV. RESULT ANALYSIS

The humidity, temperature and camera sensors provide enormous data to analyze the pollination stage of the plants. Some plants like rice, wheat, barley were analyzed for air-controlled pollination process.The following results for the growth of pollen grains were obtained from the humidity, temperature and light sensors attached row-wise in the vertical farms,

- Wheat-
  Temperature:60°F-75°F for optimal pollen development.
  Humidity:60-70%
  Light:Approximately 14 to 16 hours of light.
  Wheat grows in early summer.
- Rice-
  Temperature:75°F-90°F during day and cooler at night.
  Humidity:70-90%
  Light:Less than 12 hours of light.
  Pollen grains in rice vary due to variety of crops.
- Barley-
  Temperature:50°F-75°F for optimal pollen development.
  Humidity:40-60%
  Light:14 to 16 hours of light.
  It was concluded that barley grows between late spring and early summer.

Coordinating the fan operation with the flowering stage ensures that pollen is released into the airflow when it is most viable and likely to achieve successful pollination.

Historical data stored in databases is used to analyze trends and make future plans. Machine learning models play a crucial role in making data-driven decisions for optimizing crop production strategies. The Ml algorithms analyze these conditions and send the information back to the Raspberry Pi for device control. Based on this analysis, the fans are enabled or the velocity is adjusted accordingly to facilitate wind pollination. When the Python script receives commands, it triggers the execution of certain actions. If the pollination stage is detected, the Raspberry Pi's GPIO pin is set to high, activating the relay module that turns on the fan.

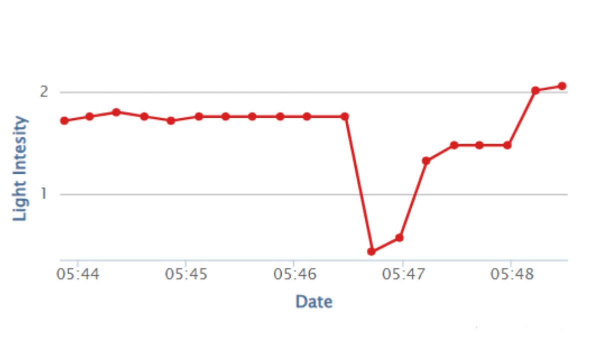


Fig. 4. Fig. 4. Light Sensor Graph

Pollen grains are transported by the airflow and can come into contact with the stigma, which is part of the female reproductive organ (pistil). This contact is critical for successful pollination. When pollen grains land on a compatible stigma, they can germinate and grow pollen tubes, allowing male gametes (sperm cells) to be transferred to the ovule, leading to fertilization.

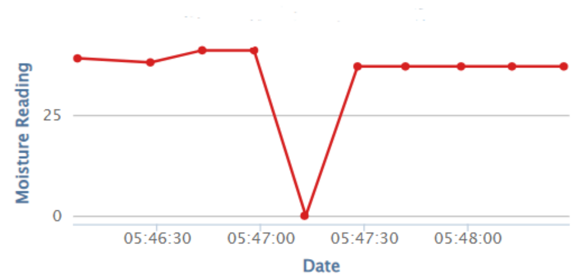


Fig. 5. Fig. 5. Moisture Sensor Graph

The placement and design of fans play a vital role in creating efficient airflow patterns within vertical farming structures. By positioning the fans strategically, farmers can achieve an even distribution of pollen throughout the growing area, which ultimately improves the success rate of pollination. To optimize the spread of pollen, farmers can make adjustments to the fan speed and direction as needed.

By controlling air currents with precision, this technology mimics the natural process of wind pollination. This ensures that pollen is transferred effectively and leads to strong crop yields. By carefully adjusting parameters such as air velocity and direction, synchronized with the development stages of plants, we have created an efficient, effective, and sustainable method of pollination for vertical farming.

## V. CONCLUSION

The problems presented by the absence of natural pollinators in vertical farming have been solved by innovative solutions that combine technology and ecological understanding. This research explored the complex balance of pollination in traditional agriculture and the unique obstacles it faces in the controlled environment of vertical farms. By delving into different methods of artificial pollination, this study underscored the importance of addressing this issue for a sustainable future of agriculture.

The introduction of airborne pollination techniques represents a breakthrough to overcome the limitations faced by vertical farmers. Through precise manipulation of air currents, this technology mimics the delicate process of wind pollination, ensuring seamless pollen transfer and consequently robust crop yields.

This research not only offers a solution to an urgent challenge, but also underlines the importance of interdisciplinary approaches in agriculture. Combining botanical knowledge, engineering expertise and technological innovation has led to the development of state-of-the-art techniques that increase productivity, support biodiversity and significantly contribute to the environmental sustainability of vertical farming practices.

As the world grapples with the increasing demands of a growing population and the environmental limitations of traditional agriculture, the findings of this study are promising. Not only do they enable vertical farmers to implement viable solutions, but they also highlight the transformative potential of scientific innovation to address global food security challenges. However, with the advancements in technology and the increasing demand for sustainable food production, IoT based vertical farming is likely to play an important role in the future of agriculture.[**8**]

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