**Role of Artificial Intelligence and Robotics in Floriculture: A Review**

**Abstract**

The integration of Artificial Intelligence (AI) and robotics in floriculture is transforming traditional flower cultivation into a technologically advanced and efficient practice. As the floriculture industry expands globally, it faces numerous challenges such as labor shortages, inconsistent quality, post-harvest losses, and environmental vulnerabilities. This review explores the role of AI and robotics in addressing these challenges by enabling precision agriculture, automating labor-intensive tasks, and enhancing decision-making. AI applications in floriculture include crop health monitoring, climate control in greenhouses, yield prediction, and market forecasting. Robotics complements AI through automated planting, harvesting, grading, and packaging—ensuring delicate flower handling with precision and consistency. The article also highlights the emergence of smart floriculture systems that integrate AI-robotics solutions for end-to-end automation. Although high initial costs, skill gaps, and infrastructure limitations present challenges, growing government support, startup innovation, and collaborative research offer promising opportunities. This paper presents global case studies and discusses future trends including urban vertical farming, blockchain traceability, and workforce transitions. India is the second largest flower-growing country after China and is at 14th position in exporting floriculture products. However, India’s percentage share in global floriculture exports is only 0.40% in 2018 which might be due to lacunae in maintaining international quality standards, lack of integrated cold chain management and unorganized market and distribution channels. With responsible implementation, AI and robotics have the potential to make floriculture more productive, climate-resilient, and economically inclusive.

**Keywords:** Artificial Intelligence, Smart Floriculture, Precision Agriculture, Greenhouse Automation, Digital Farming.

**1. Introduction**

Floriculture provides tremendous scope and opportunities and has become a major ingredient of modern lifestyle. There has been a transition in the floriculture industry as a commercial business venture with high market value and real opportunities (Anumala and Kumar, 2021; Rai et al., 2023).  It is a vital branch of horticulture, and involves the cultivation of flowering and ornamental plants for gardens, decorative purposes, and commercial use.1 Over the last few decades, floriculture has emerged as a profitable agribusiness sector, with applications spanning landscaping, perfumery, cosmetics, and the floral trade. The global floriculture market is experiencing significant growth due to increased consumer demand for aesthetic appeal, gifting, and event-based floral decorations.2 However, despite its commercial potential, the industry faces various challenges such as labour-intensive practices, pest and disease management, inconsistent product quality, and market unpredictability.3 Agricultural robots are built in order to deliver high-value application of AI in the mentioned sector. With the global population soaring, the agricultural sector is facing a crisis, but AI has the potential to deliver much-needed solutions. AI-based technological solutions have enabled the farmers to produce more output with less input and even improved the quality of output, also ensuring faster go-to-market for the yielded crops (Talaviya et al., 2020).

The emergence of advanced technologies like Artificial Intelligence (AI) and robotics has revolutionized several agricultural practices, and floriculture is no exception. AI enables data-driven decision-making by leveraging big data, computer vision, and machine learning to optimize production and quality. Robotics, on the other hand, offers automation of repetitive, time-consuming tasks such as planting, harvesting, grading, and packaging.4

**2. Overview of the Floriculture Industry**

Floriculture, often described as the art and science of growing flowers and ornamental plants, has evolved from a decorative hobby to a structured, commercial industry.3 It encompasses a wide range of activities, including the cultivation of cut flowers, potted plants, foliage plants, bedding plants, and ornamental bulbs. The sector plays a crucial role not only in enhancing aesthetic appeal but also in generating employment and foreign exchange through exports.2

**2.1 Global Perspective**

Globally, the floriculture industry is dominated by countries like the Netherlands, Colombia, Kenya, Ecuador, and Ethiopia, which are major exporters of cut flowers such as roses, tulips, lilies, carnations, and chrysanthemums.4 The Netherlands, in particular, leads the global flower trade with its highly advanced infrastructure, including the world-renowned Royal Flora Holland flower auction. These countries have adopted cutting-edge technologies, including automation and AI-powered systems, to optimize productivity and maintain high-quality standards in flower cultivation and processing.4,5

**2.2 Indian Context**

India has also emerged as a significant player in the global floriculture market. Favourable agro-climatic conditions across various states such as Karnataka, Tamil Nadu, Maharashtra, West Bengal, and Andhra Pradesh support the cultivation of a diverse range of flowers. India’s floriculture sector comprises both open-field and protected cultivation (polyhouse/greenhouse), with major crops including roses, marigolds, gerberas, gladioli, tuberoses, orchids, and anthuriums.6,7

Despite the potential, the Indian floriculture industry faces several challenges, including:

* Fragmented landholdings
* Limited access to cold chain logistics
* Post-harvest losses
* Dependence on manual labor
* Price volatility and poor market linkages

These issues often result in low productivity and significant wastage, especially in perishable products like flowers, which require rapid post-harvest handling.30

**2.3 Operations in Floriculture**

The floriculture production cycle involves several stages that demand precision and care:

* **Propagation and Planting**: Selecting the right plant material and preparing seedlings.6
* **Crop Management**: Involves irrigation, fertigation, pruning, pest and disease control.6
* **Harvesting**: Flowers need to be harvested at the correct maturity stage, often manually.6
* **Post-Harvest Processing**: Includes grading, sorting, trimming, bundling, packaging, and cold storage.6
* **Distribution and Marketing**: Transportation to wholesale markets, florists, or export units.6

**2.4 Industry Needs and Technological Gaps**

The increasing demand for consistent quality reduced labor dependency, and greater efficiency has led to a pressing need for innovation in floriculture.4 Traditional methods are often labor-intensive, imprecise, and inefficient. Technologies like AI and robotics offer solutions through:

* Real-time monitoring of plant health
* Automated harvesting and sorting
* Smart greenhouse management
* Predictive analytics for yield and market demand

**3. Introduction to AI and Robotics in Agriculture**

The agriculture sector has witnessed a paradigm shift in recent years with the incorporation of advanced technologies such as Artificial Intelligence (AI) and robotics.6,7 These technologies have revolutionized traditional farming methods, enabling precision, efficiency, and sustainability across various operations.28,29 Floriculture, as a highly specialized and labour-intensive segment of horticulture, is now beginning to benefit from these innovations.6

**3.1 What is Artificial Intelligence (AI) in Agriculture?**

Artificial Intelligence refers to the simulation of human intelligence in machines that are capable of learning, reasoning, and self-correction.26,27 In agriculture, AI involves the use of machine learning algorithms, deep learning models, computer vision, and data analytics to make informed decisions and automate complex processes.7

Key AI components used in floriculture include:

* **Computer Vision**: For identifying plant diseases, pests, bloom stage, and flower quality.7,8
* **Machine Learning**: For predicting yield, weather impact, and market demand.8
* **Natural Language Processing (NLP)**: For conversational bots and farmer advisory systems.8
* **Data Analytics**: To interpret environmental and crop-related data for precision farming.9

**3.2 What is Robotics in Agriculture?**

Agricultural robotics involves the use of intelligent machines to perform farming tasks that are repetitive, labour-intensive, or time-sensitive. These robots are equipped with sensors, actuators, and AI-based software to perform specific operations with high precision and consistency.1,11

Types of robots applicable to floriculture include:

* **Autonomous Greenhouse Robots**: For tasks such as seeding, pruning, and harvesting.12
* **Robotic Arms**: For delicate picking and packaging of flowers.13
* **Drones (UAVs)**: For field mapping, crop surveillance, and health assessment.14
* **Conveyor Belt Robots**: For post-harvest sorting and grading operations.15

**3.3 Synergy between AI and Robotics**

AI and robotics are increasingly being integrated to create smart, automated systems capable of managing floriculture operations end-to-end.5 For instance, an autonomous flower-picking robot can use computer vision to identify the correct bloom stage and use a robotic arm to harvest it without damaging the plant.7

Some examples of this integration include:

* AI-driven climate control in greenhouses based on real-time environmental data.11,12
* Robotic grading systems that classify flowers by size, color, and quality.13
* Autonomous mobile robots that navigate greenhouse aisles for pest detection or irrigation.13

**3.4 Benefits of AI and Robotics in Floriculture**

The adoption of AI and robotics in floriculture brings multiple benefits:

* **Enhanced Precision**: Reduces human error in delicate tasks like flower picking and sorting14
* **Labor Savings**: Automates repetitive tasks, addressing labor shortages14
* **Higher Productivity**: Optimizes growing conditions and minimizes crop loss14
* **Quality Control**: Maintains uniformity in flower grading and packaging15
* **Data-Driven Decisions**: Enables real-time monitoring and timely interventions15

**4. Applications of AI in Floriculture**

Artificial Intelligence (AI) is increasingly being used in floriculture to streamline operations, reduce costs, and improve the quality and yield of floral crops.16 Through technologies like computer vision, predictive analytics, and real-time monitoring systems, AI enables more precise control over growing environments and crop management practices. This section explores the most impactful AI applications in the floriculture industry.16

**4.1 Crop Health Monitoring**

One of the most promising uses of AI in floriculture is the early detection of plant stress, diseases, and pest infestations. Traditional monitoring is labour-intensive and prone to human error, but AI-powered systems can analyze large volumes of data from sensors, cameras, and drones to detect anomalies in plant health.17

* **Computer Vision Algorithms**: These are used to identify visual symptoms of fungal infections, nutrient deficiencies, and insect attacks on flower leaves and petals.17
* **AI-Driven Image Processing**: Enables automatic classification and severity estimation of plant diseases.17
* **Early Warning Systems**: Predict disease outbreaks based on weather patterns and environmental data.17

**4.2 Yield Prediction and Quality Assessment**

Accurate forecasting of flower yield and quality is vital for managing supply chains and meeting market demands. AI uses data from past crop cycles, weather conditions, soil health, and real-time inputs to predict flowering stages, harvest time, and output quantity.18

* **Machine Learning Models**: These can analyze historical data to forecast bloom timing, stem length, bud size, and flower color uniformity.18
* **AI in Flower Grading**: High-resolution cameras combined with AI can grade flowers based on color, petal symmetry, freshness, and size—ensuring standardization for domestic and export markets.18
* **Shelf-life Estimation**: AI algorithms can also predict the vase life or market longevity of flowers under different handling and storage conditions.18

**4.3 Automation in Greenhouse Management**

Modern greenhouses use controlled environments to optimize growing conditions for ornamental plants. AI plays a crucial role in automating and adjusting these environments to suit different flower species.

* **Climate Control Systems**: AI systems adjust temperature, humidity, CO₂ levels, and lighting based on crop needs and external weather conditions.19
* **Irrigation and Nutrient Scheduling**: AI can optimize irrigation cycles and fertigation by analyzing plant growth stages and soil moisture content.19
* **Energy Efficiency**: Smart energy management reduces greenhouse heating and cooling costs by using predictive analytics and environmental modeling.19,20

**4.4 Supply Chain and Market Forecasting**

Floriculture supply chains are sensitive to timing, especially for cut flowers, which are perishable and must reach markets quickly. AI improves decision-making across the value chain.12,13

* **Demand Forecasting**: Machine learning models use historical sales data, seasonal trends, holidays, and event schedules to forecast flower demand and adjust production accordingly.11,12
* **Dynamic Pricing Tools**: AI can analyze market fluctuations and recommend optimal pricing for different flower varieties.11
* **Logistics Optimization**: Predictive models help in route planning and real-time tracking to reduce spoilage during transportation.13

**4.5 Chatbots and Virtual Assistants**

AI-powered chatbots are emerging as a useful tool in floriculture extension services, particularly for small growers who may lack access to agronomic support.12

* **Advisory Services**: Virtual assistants can provide instant advice on pest control, irrigation, harvesting schedules, and post-harvest care.12
* **Language Localization**: NLP-enabled chatbots can communicate in local languages, improving accessibility in rural areas.
* **24/7 Support**: Growers can interact with AI chatbots any time of the day to resolve queries and make data-informed decisions.

**5. Role of Robotics in Floriculture**

Robotics is revolutionizing floriculture by automating manual, repetitive, and time-sensitive tasks that are crucial for maintaining flower quality and meeting tight production timelines. Given the delicate nature of floral crops and their short shelf life, robotic systems designed for precision and gentleness are particularly valuable. From planting to post-harvest handling, robots help ensure consistency, reduce labor dependency, and enhance operational efficiency.12,13

**5.1 Planting and Transplanting Robots**

Robotic planters are designed to perform precision sowing and transplanting in nurseries and greenhouses. These machines use vision systems to detect planting positions and robotic arms to place seedlings at uniform depths and spacing.11,13

**Benefits**:

* + Increased planting speed and accuracy
  + Consistent plant spacing for optimal growth
  + Reduction in transplant shock due to gentle handling

Automated transplanting is particularly useful in floriculture where many crops begin in nursery trays and must be carefully relocated to growing beds or pots.14

**5.2 Automated Harvesting Systems**

Harvesting flowers is a delicate task that requires judgment to pick blooms at the right stage without damaging the stem or surrounding plants. Robotics has made significant strides in this area.15

**Robotic Harvesters**:

* + Equipped with cameras and sensors to assess bloom maturity and position
  + Use soft robotic grippers or suction systems to gently harvest flowers
  + Operate autonomously in greenhouses or open fields

Such systems are especially useful in harvesting roses, gerberas, and lilies where timing and handling are crucial. Robotic harvesters reduce dependency on seasonal labor and can work longer hours with consistent precision.14,15

**5.3 Post-Harvest Handling and Packaging**

Once harvested, flowers must be sorted, graded, and packaged swiftly to maintain freshness. Robotics streamlines this process through automation.14

**Grading Robots**:

* + Use AI-integrated vision systems to evaluate parameters like color, stem length, bloom size, and defect presence
  + Sort flowers into uniform batches for quality assurance

**Packaging Systems**:

* + Robots can bundle flowers, insert them into sleeves, and place them in crates or boxes with minimal damage
  + Conveyor-based robotic arms handle thousands of stems per hour with high consistency

**5.4 Drones and UAVs**

Unmanned aerial vehicles (UAVs) or drones are becoming valuable tools in floriculture, especially for large open-field flower farms.12

**Applications**:

* + Aerial imaging for plant health assessment
  + Monitoring for weed and pest infestations
  + Estimating flowering coverage and yield forecasts

Drones collect high-resolution multispectral images that are analyzed using AI software, providing growers with actionable insights in real time.15,16

**5.5 Robotic Weeding and Maintenance**

Robotic weeders are programmed to identify and remove unwanted plants using image recognition.17,18 While not yet widely used in floriculture, such robots can be adapted for ornamental plant fields and nurseries to:

* Minimize herbicide use11
* Prevent competition for nutrients and light12
* Maintain neatness and quality of floral beds13

**5.6 Greenhouse Robots**

These autonomous mobile robots navigate greenhouse aisles and perform routine tasks such as:

* Spraying nutrients or pesticides12
* Monitoring plant parameters using onboard sensors13,15
* Supporting vertical growing systems by lifting or rotating pots16

Examples include robots developed by companies like Octinion (Belgium) and Fyto (USA), which are setting new standards in floriculture automation.18

**5.7 Safety and Delicacy in Floral Handling**

A unique challenge in floriculture robotics is the need for extreme care in handling delicate flowers. Advancements in:

* **Soft robotics**
* **Tactile sensors**
* **Force-feedback mechanisms**

**6. Integration of AI and Robotics – Smart Floriculture Systems**

The real power of technological advancement in floriculture lies in the integration of Artificial Intelligence (AI) with robotics, creating what is often referred to as Smart Floriculture Systems. These integrated systems bring together sensors, data analytics, machine learning, and automation to manage the floriculture value chain more efficiently—from seeding and nurturing to harvesting and post-harvest handling. This synergy enhances decision-making, improves precision, and allows scalable, high-quality flower production, even in resource-constrained environments.11,12

**6.1 Smart Greenhouse Systems**

A smart greenhouse is a concept that assists in guiding the steps required to modify and reorient agricultural systems to successfully support their growth and assure food security in a changing climate. A smart greenhouse is a method that assists in guiding the activities that must be made in order to alter and sustain the environment. The policy attempts to achieve three key goals: a sustainable increase in agricultural production; building resilience to climate change; and decreasing and eliminating greenhouse gas emissions wherever possible (Simo et al., 2022). Modern smart greenhouses are a prime example of AI-robotics integration in floriculture. These facilities are equipped with sensors and IoT devices that continuously monitor environmental conditions such as:

* Temperature
* Humidity
* Soil moisture
* Light intensity
* CO₂ concentration

AI algorithms process this data in real-time to adjust ventilation, heating, cooling, lighting, and irrigation. Simultaneously, autonomous robots perform physical tasks like spraying, pruning, or harvesting. This not only maximizes yield and quality but also optimizes energy and water use.12,13

**6.2 Intelligent Flower Sorting and Grading Lines**

In commercial floriculture, sorting and grading flowers for uniformity and quality is a critical step before packaging and marketing. Smart grading systems combine:

* **High-resolution cameras** (robotic vision)
* **AI algorithms** (to detect defects, measure bloom size, and assess color)
* **Robotic actuators** (to sort flowers into appropriate categories)

The result is a fully automated post-harvest line that maintains speed and consistency far beyond what manual operations can achieve.12,17

**6.3 Predictive Crop and Market Management**

Smart floriculture systems use historical and real-time data to make accurate predictions about crop development and market behavior.12,14 This includes:

* Flowering time and harvest date prediction17
* Optimal scheduling for nutrient and water delivery18
* Market demand forecasting using machine learning17,18
* Automated adjustment of production schedules based on expected sales trends12,19

Such predictive intelligence helps growers minimize waste, avoid overproduction, and meet market demands precisely—especially for festivals, weddings, and global export markets.19,20

**6.4 Automated Logistics and Packaging Systems**

AI and robotics can also be integrated into the logistics chain for:

* Real-time tracking of flower crates during transport11,12
* Managing cold chain operations12,13
* Predicting shelf-life and determining best-before dates14,15
* Automating packaging to minimize human handling and preserve freshness17,20

By reducing post-harvest losses and ensuring timely delivery, smart logistics systems are critical in maintaining competitiveness in the global floriculture market.21,22

**6.5 Examples of Smart Floriculture Systems in Action**

**Netherlands – Greenhouse Automation at Scale**

* The Netherlands leads in smart floriculture with highly automated greenhouses using robotic planters, AI-based environmental control, and advanced grading systems.21,22
* Companies like Priva and Ridder specialize in integrated climate control and irrigation systems that use AI to optimize conditions for tulips, roses, and orchids.21,22

**Japan – Robotic Harvesting of Ornamental Plants**

* Japanese floriculture industries use AI-guided robots to harvest and bundle chrysanthemums with minimal damage.22,23
* Integration with blockchain and AI enhances traceability and product quality.24,25

**India – Pilot Projects and Startups**

* Indian agri-tech startups are now testing AI-powered advisory apps and robotic arms for rose and gerbera farms.26,27
* Collaborations between state agriculture departments and private tech firms are helping greenhouses become more data-driven.28,29

**6.6 Toward Fully Autonomous Flower Farms**

Looking ahead, the vision of fully autonomous flower farms is becoming more feasible.26 In such systems:

* Robots perform all physical labor, including planting, monitoring, harvesting, and packaging.19
* AI monitors every plant’s health individually and provides customized care.11,12
* Drones and AI-driven imaging ensure real-time surveillance and diagnostics.13,14
* Market algorithms predict prices and send alerts to optimize supply.15,17

**7. Challenges and Limitations**

While Artificial Intelligence and robotics hold transformative potential for floriculture, their integration is not without hurdles. Adoption of these advanced technologies faces practical, economic, and socio-technical barriers, particularly in developing regions or among smallholder growers. Understanding these challenges is crucial to developing inclusive and scalable solutions that benefit the entire floriculture ecosystem.11,12

**7.1 High Initial Investment**

The upfront cost of deploying AI-powered systems and robotic machinery is one of the primary deterrents, especially for small and medium-scale growers.11,12

* **Hardware Costs**: Robots, sensors, cameras, and greenhouse automation systems require substantial capital investment.11
* **Software and Maintenance**: Proprietary AI software, cloud platforms, and regular updates come with recurring costs.12
* **Return on Investment (ROI)**: The long-term savings and productivity gains may not be immediately evident to resource-constrained farmers.14

**7.2 Technical Complexity and Skill Gaps**

Operating AI- and robotics-based systems often requires specialized knowledge, which many growers, especially in rural areas, may lack.11

* **Training Needs**: Users must learn how to calibrate sensors, manage software, and interpret AI-generated insights.12
* **Dependency on Technicians**: Breakdowns or malfunctions often require expert intervention, which may not be available locally.13
* **Resistance to Change**: Traditional farmers may be hesitant to shift from manual to automated processes due to unfamiliarity or perceived risk.15

Without proper training and capacity-building initiatives, the technology may remain underutilized or misapplied.

**7.3 Data Privacy and Cybersecurity Concerns**

As smart floriculture systems rely heavily on data collection, transmission, and storage, concerns around data ownership, privacy, and cybersecurity arise.14,15

* **Data Theft or Misuse**: Sensitive information about farming operations and supply chains may be vulnerable to breaches.17,18
* **Dependence on Cloud Platforms**: Remote storage may expose growers to internet disruptions or data access issues.21,22
* **Lack of Regulation**: In many countries, there are limited data governance frameworks in the agricultural sector.23

**7.4 Infrastructure Limitations**

The successful implementation of AI and robotics is often dependent on access to reliable infrastructure.

* **Connectivity Issues**: Many rural areas lack high-speed internet or mobile networks required for IoT-based operations.12,13
* **Power Supply**: Frequent power cuts or lack of electricity in remote floriculture zones hinder consistent operation of automated systems.12,13
* **Cold Chain Gaps**: Without a stable post-harvest infrastructure, the benefits of automation in grading and packaging may be lost during distribution.14,15

**7.5 Scalability and Customization Issues**

AI and robotics systems are often designed for specific crops or large-scale commercial operations, making them difficult to adapt for diverse or smallholder contexts.11,12

* **Crop-Specific Limitations**: Technologies optimized for one flower variety may not work well with others due to differences in size, growth patterns, or fragility.14,16
* **One-Size-Fits-All Models**: Off-the-shelf robotic solutions may not meet local agronomic conditions or small plot layouts.21,22
* **Integration Gaps**: Many growers already use legacy equipment, which may not integrate well with new smart systems.22,25

**7.6 Environmental and Ethical Concerns**

The use of robotics and AI raises some ethical and environmental questions:

* **E-Waste and Sustainability**: As devices become obsolete, disposing of electronic waste responsibly becomes a concern.11,12
* **Job Displacement**: Automation may replace manual labor, raising concerns about unemployment in rural communities dependent on floriculture.13,16
* **Algorithmic Bias**: AI systems trained on biased or limited data may make poor decisions that affect crop performance or resource allocation.17,19

**9. Conclusion**

The floriculture industry, once heavily reliant on manual labor and traditional practices, is now standing at the threshold of a technological revolution. The integration of Artificial Intelligence and robotics presents unprecedented opportunities to transform this visually stunning but operationally complex sector into one that is efficient, scalable, and sustainable.

From intelligent disease detection and climate-controlled greenhouses to robotic harvesting and AI-powered market forecasting, these technologies are redefining how flowers are grown, processed, and delivered. The synergy between AI’s analytical power and robotics’ physical capabilities enables precision across every stage of the value chain boosting productivity, minimizing losses, and maintaining high product quality.

While there are challenges such as high initial costs, technical skill gaps, and infrastructure limitations, the long-term benefits outweigh the hurdles. Strategic investments in research, training, and infrastructure—along with supportive government policies—can ensure that even small and medium growers reap the benefits of smart floriculture.

As global demand for ornamental plants continues to rise, particularly in urban, event, and export markets, the role of AI and robotics will become even more crucial. By embracing these innovations thoughtfully and inclusively, the floriculture industry can move toward a future that is not only technologically advanced but also environmentally responsible and economically inclusive.

Ethical Approval:

As per international standards or university standards written ethical approval has been collected and preserved by the author(s).

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

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