

Smart technologies in ornamental horticulture

Digital technology has played a prominent role in precision agriculture particularly Internet-of-things (IoT) and Artificial intelligence (AI). These technologies use drones, sensors and GPS mapping to optimize the crop inputs with concomitant increase in yields and significant reduction in waste. Monitoring of plant growth and health would enable growers to supplement precise fertilization and irrigation as well as pest management practices which will ultimately reduce the environmental impact on flower production.

FLORICULTURE industry is a part of lifestyle horticulture industry worth USD 300 billion. Lifestyle horticulture comprises of many verticals including cut flowers (USD 10.40 billion), live plants (USD 10.00 billion), cut foliage (USD 1.48 billion), flower seeds (USD 7.64 billion), live trees, plants, bulbs, cut flowers (USD 26.50 billion), dried flowers (USD 609 million), value-added products like bouquets (USD 11.00 billion), amenity horticulture, turf and arboriculture etc. Flowers have always been an integral part of Indian culture. They have been cultivated for aesthetic purposes, as also for their fragrance and extraction of nutraceuticals. Traditional flowers remain the backbone of Indian floriculture with 95% of area out of 296,000 ha under loose flowers producing 2,284,000 MT. Cut flowers are grown in the remaining 5% of the area producing 946,000 MT of different cut flowers (Advanced estimates 2023-24).

Consistent demand for new varieties to cater varied consumer preferences, shrinkage of natural resources coupled with climatic vagaries kindled to look for an alternative method of cultivation. Digital technology has played a prominent role in precision agriculture particularly Internet-of-things (IoT) and Artificial intelligence (AI). These technologies use the drones, sensors and GPS mapping to optimize the crop inputs with concomitant increase in yields and significant reduction in waste. Monitoring of plant growth and health would enable growers to supplement precise fertilization and irrigation as well as pest management practices which well ultimately reduce the environmental impact on flower production. Moreover, deploying robotics and automation have played a prominent role in reducing labour costs with increased efficiency in flower cultivation. For instance, automated planting-cum-harvesting systems performed tasks with much rapid pace than manual labour which reduces the cost of labour.

Application of smart technologies is evolving rapidly in floriculture in developed nations. Recent developments in the area of digital applications in floriculture are discussed in this article.

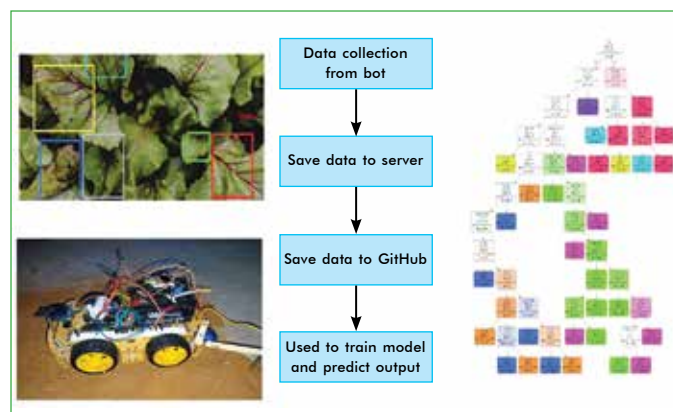
Internet of Things (IoT) in floriculture

IoT involves the use of interconnected devices and sensors to collect real-time data on various parameters. Sensors placed in fields monitor soil moisture, temperature, humidity, and nutrient levels. Automated irrigation systems use this data to optimize water usage, reducing waste and improving crop health. IoT also enhances supply chain management by tracking produce from farm to market, ensuring quality and reducing spoilage.

Artificial Intelligence (AI)

AI complements IoT by analyzing the vast amounts of data collected, providing actionable insights and predictions. Machine Learning (ML) algorithms process data to predict weather patterns, pest outbreaks, and crop diseases, enabling farmers to take preventive measures. AI-powered drones and remote sensing technologies monitor crop health and field conditions, identifying issues like nutrient deficiencies, pest infestations, and disease outbreaks early. AI also aids in precision farming by recommending optimal planting schedules as well as irrigation and fertilization practices based on data analysis.

The combination of IoT and AI in floriculture leads to more efficient resource use, higher crop yields, and reduced environmental impact. It empowers farmers with real-time information and predictive analytics,



Model system of IoT



Black spot of roses (Diplodia) can be detected by image based diagnostic tools using AI

facilitating informed decision-making. This technological convergence is crucial for addressing challenges such as climate change, population growth, and food security, ensuring a sustainable and productive agricultural future. The Internet of Things (IoT) and AI in floriculture, also known as Smart Farming, involves using interconnected devices and sensors to collect and analyze data, enhancing efficiency and productivity both in field and controlled systems.

Robotics in production, harvesting and management

Smart greenhouses

It is estimated that by 2050, the IoT will increase the yield by 70% in horticulture. IoT is a powerful technical support to agriculture. Smart greenhouses are one of typical IoT agriculture examples. A smart farm is capable of automatically controlling environmental conditions such as temperature based on its database customized for different crops. Even sprinkling of pesticides can be done without the intervention of farm labour. All environmental elements such as humidity, light and ventilation are managed by the smart farming system. It is believed that the amount of produce can increase approximately 30% with the help of the solution. Retractable greenhouses equipped with IoT would transform future farming of floricultural crops.

Mechanization in protected cultivation of flowers

Protected cultivation is an intensive production system which requires high investment and operational costs thereby limiting its usage in production systems. Automation and robotics are the only ways to circumvent these constraints. The unstructured and variable crop environments pose challenges for implementation of automation and robotics.

In recent years, a harvesting robot for roses has been developed and tested under field circumstances in the Netherlands. In this case, the rose is moved to the robot instead of the robot moving to the plants in the greenhouse. During the harvest cycle, a camera system travels over the rose plants and locates the roses to be harvested. Thereafter, the harvesting operation is performed with two manipulators. One manipulator grips the rose just below the flower and pulls it gently aside to generate space for the second manipulator to travel down the stem towards the point where it will cut the stem. This manipulator carries a small sized stereovision system that is used for real time tracking of the stem during this downwards motion. Upon arrival, the manipulator

deploys a small scissor type cutter that will cut the stem. Finally, the rose is pulled out and put in storage by the first manipulator whilst the second manipulator moves out of the crop and will proceed with the next harvest cycle. A prototype to harvest apples on similar lines is being developed at ICAR-CITH, Srinagar.

A pot-rose cutting production robot, the Rombomatic, is being used. Using camera vision and industrial manipulators, the machine produces rose cuttings from stock material. Stock material is manually fed into the machine and then processed by a camera-vision controlled industrial manipulator. Cuttings are dipped in root growth stimulating powder and stuck into the soil. The machine can also be used to produce cuttings of some other potted plants.

Grafting is a delicate process which requires a high degree of skill and the operation is both physically and mentally demanding. A grafting robot was developed. The grafting robot achieved a success rate of 97% at a speed 10 times faster than human workers. This machine is commercially available and can be used for grafting cucumber, water melon, melon, tomato and eggplant at a capacity of 800 plants per hour. ICAR-DFR has developed a prototype of pedal operated grafting machine, which is being recalibrated for various rootstocks of rose. The grafting machine can be recalibrated and upgraded with robotic capabilities.

Sorting lines consisting of buffered feeders, maturity measurement, length and thickness measurement besides automatic bunching and sealing machines are used for sorting roses and gerbera with a capacity of up to 15,000 gerberas per hour (gerbera). Camera vision is used to assess the maturity of flowers. New developments in sorting roses are focused on assessing the maturity and quality of flowers automatically. New technologies based on fluorescence technology and 3D measurements to calculate the diameter (cut-anthurium, gerbera, rose) are used in the near future. A Dutch company called Havatec is using X-ray to sort alstroemeria flowers, tulip flowers and tulip bulbs and 3D stereovision for measuring the diameter of the calyx of anthurium.

Intelligent sensors and software to support human tasks with intelligent guided transport are evolving in floriculture. Intelligent guided transport of buffer and labour intelligent transport systems have been developed to transport labour and storage buffers to and from the growing area. Automatic Guided Vehicles (AGV) can change speed automatically adjusted to the human workload. When the buffer on the AGV is full, it will



Hydroponics in tuberose



Plant protection measures in tuberose using drone

automatically find its way to a place where further handling is done and another AGV is waiting where labour can hop on. A central system is detecting all the AGVs in the production area to monitor logistics and prevent problems. These intelligent AGVs can be found in tomato, rose, gerbera, sweet-pepper and cucumber.

Dutch companies who introduced AGVs for greenhouses are Metazet, Berg Product and Koat.

Mechanization of nursery operations

To minimize drudgery in nursery industry and also address the dwindling labour force, smart automation is crucial for different operations like bed making, media mixing, media filling, sowing, watering, makings cuttings, weeding, periodical pruning etc.

Scheduling

Scheduling is an important facet of cut flower production to optimize production and timing, thereby preventing market glut and improving profitability of growers. Market information is compiled and the crop planting, cropping area and the planting material as well as other requirements are worked out. Scheduling will optimize the cropping area, planting material requirement and will also help in avoiding mismatch of arrivals in the market. Many interactive decision support tools (Flowers on Time, Virtual Grower 3.0) have been developed which facilitates scheduling.

Flowers on time was developed by Paul Fisher (University of Florida), Erik Runkle (Michigan State University), Matthew Blanchard (Michigan State University) and John Erwin (University of Minnesota). It is a computer decision support tool in Microsoft excel that determines how the greenhouse air temperature would influence flowering in about 60 odd flower crops. It will help in economizing heating costs and achieve targeted flowering at an appropriate time.

Users of Virtual Grower 3.0 software can build a greenhouse with different materials, designs, schedule temperature points throughout the year and predict heating costs. Different heating and scheduling scenarios can be predicted with inputs from a few variables with accurate data from historical records of USDA for 35 flower crops.

Modelling in floriculture

Functional-structural plant models (FSPMs, also known as virtual plants) can be defined as models explicitly describing the development over time of the

three-dimensional (3-D) architecture or structure of plants as governed by physiological processes which, in turn, are driven by environmental factors. This modelling approach is particularly suited to integrate and apply knowledge on plant architecture and bud break. In particular, feedback between structure and function can be implemented and verified at various levels, e.g. locally at the organ scale and globally at the plant or canopy scale.

Wearables for diagnostics

Detection and identification of diseases in crops could be realized via both direct and indirect methods. Direct detection of diseases includes molecular and serological methods that could be used for high-throughput analysis when large numbers of samples need to be analyzed. In these methods, the disease causing pathogens such as bacteria, fungi and viruses are directly detected to provide accurate identification of the disease/pathogen. On the other hand, indirect methods identify the plant diseases through various parameters such as AI based algorithms, morphological change, temperature change, transpiration rate change and volatile organic compounds released by infected plants. ICAR-DFR pitched a concept in the ICAR-Hackathon on smart technologies recently. The concept envisages dynamic recording of micro- and macro-climates in open and protected environments continuously through a series of sensors and data loggers to determine predisposing conditions for the onset of a pest or disease outbreak. Through a dedicated decision support system (App), an alert is sent to a wearable (smart watch or a phone) a farmer uses to take timely preventive measures.

Drone technology

Drone usage has become a reality in floriculture in recent times with the introduction of ambitious programme of Ministry of Agriculture and Farmers Welfare, Government of India to promote drone usage on a large scale. A special programme *Drone Didi* is launched by Hon'ble Prime Minister where in drones will be given to around 3,000 women self-help groups (SHGs) across several states with a subsidy of ₹ 8.00 lakh to procure agriculture drones. ICAR-DFR, has initiated research on crucial parameters like speed, height, discharge rate, droplet size, spray volume, dosage of different



Plant protection measures in chrysanthemum using drone



Powdery mildew of roses can be detected by image based diagnostic tools using AI

application of chemicals. In RHEA project (Robot Fleets for Agriculture and Forestry Management), robots are integrated in tractor units and equipped with machine vision-based weed and crop row detection systems. This approach is able to detect up to 90% of weed patches and eliminate most of them by using a combination of physical and chemical means.

Smart packaging

Owing to highly perishable nature of flowers, it is important to develop smart packaging incorporating sensors and RFID based systems to continuously record the microclimate during transit to ensure safe arrival at the destinations. The data generated would determine lapses if any during the transit so as to take preventive measures. As a prelude to such efforts, ICAR-DFR has developed foldable crates to transport flowers to economize on transportation cost and also to integrate such sensors in future.

Intelligent gardening

Scientists from Massachusetts Institute of Technology has designed and implemented 'Indoor Robot Gardening'. This indoor garden is a mesh network of robots and plants. The gardening robots are mobile manipulators with an eye-in-hand camera. They are capable of doing every garden activity from locating plants in the garden, watering them, and locating and grasping fruits. 'Green-thumb' robots are used for automatic planting or harvesting. This robot also notes the surrounding environmental conditions of the plant like temperature, moisture and humidity so that the robot will decide about health of plant and will display it on the LCD. The robot also has watering mechanism and provides water to the plants according to their requirement by observing soil moisture and humidity.

Plant doctors

Many autonomous intelligent poly house robots observing health of plant through image processing are developed at various parts of the world. Artificial neural

chemicals on flower crops and ornamental nurseries besides conducting demonstrations in farmer's fields. Drones can be effectively utilized not only for plant protection but also regular monitoring of crop health, estimation of damage during calamities for determining the crop insurance.

Global effort include, RIPPA (Robot for Intelligent Perception and Precision Application) which is a small drone like a ladybird used for identification of pest and diseases besides precision

network and fuzzy logic are utilized in designing disease detection systems. Ian Kelly and the University of West of England, Bristol, have invented a robot that will track, capture and dispose off slugs, called Slugbot, a solution to the slug problems in flower production. Georgia Tech engineers have designed robots that can sniff crop disease. It is a micro gas chromatograph; a GC-on-chip device which is able to detect crops disease based on the volatiles emitted by the plants.

Aeroponics/ Hydroponics

Models were standardized for chrysanthemum in 2019 by Proeftuin Zwaagdijk in the Netherlands. Floats make the cultivation system mobile and suitable for mechanization and automation. Microclimate above the float is very different from that above soil with good circulation. Good aeration of the nutrient solution is essential for higher yield with higher stem weight and shorter cultivation periods. In this system, plants are fixed in the floats and their root system is developed in a 30 cm deep nutrient solution.

Water management

Sensor based irrigation increased revenue by 62% and profit by 65% per year. Similarly, some studies conducted on implementation of sensor-based irrigation in commercial floriculture crops such as petunia (*Petunia × hybrida*), poinsettia, periwinkle (*Catharanthus roseus*), hydrangea, solidago, myrtle and containerized chrysanthemum showed extensive benefits of soil-moisture based automated irrigation. These studies imply that the precision irrigation system could reap dividends to the varied stakeholders involved in floriculture industry.

CONCLUSION

Using emerging technologies like the internet of things (IoT)-enabled devices such as smart agricultural sensors and robotic drones, satellite imagery, and GPS-enabled instruments, real-time data are collected on soil, crop, hyper-local weather predictions, equipment available, and other variables. This is supplemented by inputs from IoT and AI/ML-driven predictive analytics software to enhance production and productivity of floricultural crops and nursery stock.

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Septoria leaf spot of chrysanthemum can be detected by image based diagnostic tools using AI