# Innovations in Protected Floriculture; High - Tech Greenhouses and Precision Growing Systems

## P. Mamatha

Ph. D scholar, Department of Floriculture and Landscape Architecture, College of Horticulture, SKLTGHU, Rajendranagar, Hyderabad. India.

Mail id: mamatha33339999@gmail.com

## Abstract

The concept of protected floriculture has become a revolutionary solution to the production of flowers, responding to the issues of climate uncertainty, resource depletion, and growing quality requirements of both local and foreign markets. The development of new high-tech green houses and accurate growing apparatus has improved the productivity, efficiency of the input use and sustainability of the floricultural business a great deal. The use of modern, secured buildings whose climate is controlled by an automated system allows to control temperature, humidity, light intensity, and carbon dioxide level with high precision, which allows establishing the most advantageous microclimatic conditions to grow high-value flower crops throughout the year. These developments have eliminated the reliance on the seasonal condition and the production risks that are accompanied by extreme weather conditions. The implementation of precision growing systems has also transformed the sphere of the protected floriculture by allowing the use of data in making decisions. Monitoring with the use of sensors, the Internet of Things (IoT) systems, and automated fertigation systems enable real-time evaluation of plant and environmental measurements, which guarantees proper delivery of water and nutrients to the crops in terms of their specific needs. This accuracy does not only increase the quality and uniformity of flowers, but also increases water and nutrient-use efficiency, which is a factor towards environmental sustainability. Hydroponics and substrate-based cultivation methods (soilless cultivation methods) have become notable due to their capability to eliminate soil-borne diseases, enhance root-zone conditions, and increase yield/unit area. The current trends in

artificial intelligence and data analytics have presented new opportunities in intelligent floriculture. Machine learning and image based phenotyping tools are also being used to detect pests, diseases and physiological stress early to be able to intervene and minimize the use of chemicals. Moreover, decision-support systems combine both past and current data to maximize crop scheduling, energy consumption as well as performance of greenhouses. These advancements, notwithstanding, have been hampered by high initial capital requirement, technicalities and unavailability of skilled man-power that still limit the wide-scale implementation, especially by marginal and small growers.

**Introduction**

Floriculture is also among the most vibrant and most valuable areas of horticulture and has a large proportion of farm revenues, creation of employment and export incomes. Urbanization and increased incomes, expanding hospitality and event markets, and the increased aesthetic consciousness have caused the demand of cut flowers and ornamental plants to grow at an alarming rate. Nonetheless, traditional open-field floriculture is very susceptible to climatic uncertainties, pest and disease pressure and inefficient utilization of natural resources that usually lead to uneven yield and low quality produce. Such constraints have been influential in the move towards more regulated and technology-based systems of production. Protected floriculture is a potential and sustainable substitute to the open-field production because it offers a controlled environment that reduces climatic risks and maximizes production. Protected houses that include greenhouses, polyhouse, and shade-net houses enable the growers to control some of the vital environmental factors, including temperature, humidity, light intensity, and the concentration of carbon dioxide. This managed microclimate permits all year round cultivation of high value flower crops including rose, gerbera, carnation, chrysanthemum and orchids that guarantee constant quality and increased market returns. Protected floriculture has over the past years attracted much interest in both developed and developing nations as one of the strategies of enhancing productivity and achieving high product quality criteria of the local and export markets.

The potential of the protected floriculture has been continued to be enhanced by the development of high-tech greenhouse design and precision growing systems. The trend is that modern green houses are being fitted with automated climatic control, sensor-based surveillance and computer-aided management control systems which facilitate exact control of growing crop condition. With the help of Internet of Things (IoT), data analytics, and automated fertigation technologies, precision growing systems promote the effective utilization of water, nutrients, and energy so that the cost of production and environmental consequences could be lowered. These advancements are in line with sustainable farming because they would increase the efficiency of using resources and decrease their reliance on chemicals. Although it has a good potential, uptake of the protected floriculture is disproportionate owing to the high initial requirement in the technology, insufficient technical knowledge and inaccessible institutional facilities. However, the increased policy focus on agriculture resistant to climate disturbance coupled with technological progress and the falling prices of smart farming devices provides the new prospects to the development of the protected floriculture. The current paper will examine new trends in high tech green houses and precision growing systems and how they have turned the industry of floriculture into a more efficient, sustainable, and cost efficient industry.

**Protected Floriculture Concept**

Protected floriculture is a cultivation of flower crops in controlled or semi-controlled environmental conditions with the aim of enhancing productivity, quality and efficiency in the use of resources. In contrast to open-field cultivation, temperature, humidity, light intensity, photoperiod, and carbon dioxide concentration can be controlled by the growers in the circumstance of controlled floriculture, as the growth of crops directly depends on the extrinsic climatic factors. The method reduces the effects of climatic hazards, lowering the biotic and abiotic stresses, allowing the production of high-value floricultural products all year round. The principle of protected floriculture is founded on the basis of altering the natural environment of the growth to the physiological needs of flower crops. Various flowers need special climatic and light conditions to grow well, flower and develop color. The use of the protected structures

provides a physical resistance between crops and the undesirable external factors, including extreme temperatures, heavy rainfall, frost, hailstorms, and strong winds. The protected floriculture can be used to provide uniform growth, synchronized flowering, and high-quality flowers which are very important in domestic and export markets by ensuring that the optimal growing conditions are maintained. Protected floriculture includes the variety of structures and technologies that are different in their complexity, cost, and degree of environmental control. Most commonly a greenhouse, polyhouses, shade-net houses, and insect-proof net houses are the common structures that are used under protection. Green houses, especially high-tech or climate-controlled green houses, have the maximum level of environmental control with automated heating, cooling, ventilation and shading. Polyhouses are medium control with quite low prices and are highly used in the waste lands, and the subtropical areas. Shade-net houses are mainly used to control light and temperature levels and hence they are well applied to shade-loving ornamental plants whereas insect-proof net houses are used to minimize the infestation of pests and disease occurrence without excessive dependence on chemical pesticides.

One of the most important characteristics of the floriculture under protection is the adoption of better management of the crops. Precision irrigation and fertigation systems help provide water and nutrients to the root zone accurately and on schedule, eliminating waste and optimizing efficiency in the use of nutrients. Fertigation and drip irrigation is a common technique to maintain optimum soil or substrate moisture content, especially on delicate flower crops. Also, the introduction of soilless production technologies, including hydroponics and growing media consisting of a substrate, has further solidified the idea of a protected floriculture by removing soil-borne pathogens, as well as, providing a greater level of control over root-zone conditions. Protected floriculture is also considered to play a major role in integrated pest and disease management. Certain environmental conditions such as controlled environment limit the immigration of pests and suitable micro climatic control limits disease occurrence. The use of biological control agents and sticky traps, as well as environmentally friendly pest management, is more effective in the conditions of protection, which leads to safer and pesticides-free flower

production. In addition, the use of growth regulators, pruning, and training in regulated settings improves the flower size, the length of stems, color, and the vase life. Economically, the aim of the protected floriculture is to achieve maximum productivity in terms of unit area and input. Though the start up costs are significantly higher than those of open field cultivation, the payoffs can be significantly high considering the higher yields, high quality produce and targeting of off-season markets. Market-oriented and export-oriented production systems are also supported by protected floriculture; in this case, the system needs consistency in supply and quality.

**Development of the High-tech Greenhouses**

The development of high-tech greenhouses is one of the technological shifts in the exploited floriculture, which is determined by the necessity to surmount the climatic limitations, to increase the productivity, and to satisfy the growing demand of high-quality flowers during the whole year. The first forms of greenhouses were uncomplicated forms of protection buildings whose main aim was to protect crops against weather and other undesirable elements like frost, heavy rain and winds. These early constructions which were mostly glass oriented, or used locally available materials, allowed little control of the environment and were largely managed by manual means. Although they worked to some degree, they were limited by reliance on the natural climatic conditions in terms of their productivity and efficiency. The second step in the evolution of the greenhouses was the creation of the low-cost and naturally ventilated greenhouses especially in the developing countries. Popularity of polyethylene covered polyhouses was because of its low costs, simplicity, and use in tropical and subtropical climates. These buildings enhanced the flow of light and shielded crops against harsh climatic conditions, which allowed them to have very long growing seasons and better flowers. Nevertheless, the control over the environment was also partial, and temperature and humidity were mostly dependent on the external factors. The significant change has been witnessed in the establishment of medium-tech green houses with the integration of rudimentary climate controlling mechanisms. The partial control of the temperature and humidity was possible with the help of such features as roof and side ventilation, shade nets, fogging or misting systems, and

thermal screens. These systems greatly enhanced the cultivation condition of floricultural crops and this initiated the technology-enhanced cultivation. Farmers were now able to reduce heat stress and keep the moisture at its optimum, and enhance the uniformity of crops, which resulted in increased yield and high-quality flowers.

The introduction of completely automated high-technology greenhouses was a revolutionary stage in the field of protected floriculture. These high-tech constructions are undertaken with the help of high-strength materials, streamlined architectural designs and energy efficient elements in order to make them more enduring and accurate. The state of the art high-tech greenhouses have computerized climate control systems which constantly check and control the temperature, relative humidity, light intensity, carbon dioxide level, and air circulation. Large-scale flower growing involves sensors and controllers that automatically regulate heating, cooling, ventilation, and shading systems based on real-time environmental data so that the conditions are ideal to grow the flowers during the production process. High-tech greenhouses have become highly efficient in terms of energy conservation and sustainability. The innovations that have been introduced like double-layer coverings, thermal insulation screens, and energy saving heating systems have reduced the usage of energy significantly. This has further augmented sustainability that incorporation of renewable energy sources such as solar panels and geothermal systems has reduced the cost of operation. Moreover, the development of new lighting technologies, especially light-emitting diodes (LEDs), enables control of light spectrum and photoperiod to reduce flowering and consume less energy than conventional systems of lighting. The other characteristic of the current greenhouses is their incorporation with accuracy agriculture technologies. The Internet of Things (IoT) service will allow the monitoring and control of operations in the greenhouse remotely via computers or smartphones. Sensors produce data which is processed with decision-support systems and artificial intelligence to optimize irrigation, fertigation, and crop planning. Monitoring systems based on images help in the early detection of pests, diseases, physiological disorders, thus early and specific intervention can be made.

**Precision Growing Systems through Floriculture**

Precision growing systems in floriculture is a new technology in flower production involving the application of modern technologies in combination with scientific crop management to obtain high efficiency, consistency, and sustainability. Such systems target site and crop-specific management of inputs including water, nutrients, light, and climatic conditions so that flower crops only get what they require at a time they require it. Precision growing systems have been considered as a critical instrument in the context of the protected floriculture to enhance the maximum productivity and fulfill the high quality demands of the domestic and export markets. One of the essential elements of growing systems precision is the real-time control of the environmental and plant parameters. There are sensors in the greenhouse, which constantly measure the temperature, relative humidity, light intensity, carbon dioxide concentration, and the root-zone environment including moisture, electrical conductivity and pH. This is a stream of endless information that allows growers to remain in favorable microclimatic conditions that are specific to certain flower crops and their growth stages. Proper management of the parameters will assist in alleviating physiological stress, increasing the levels of nutrient uptake and other characteristics of flowers like length of stems, homogeneity of the buds, the color intensity and longevity of the vases. Precision floriculture is based on automated irrigation and fertigation systems. Precision systems can be used in contrast to the traditional approach to use fixed schedules, where water and nutrients are applied, which is determined by the demand of crops, the rate of evapotranspiration, and the state of substrates. Drip irrigation with computerized fertigation units enables delivery of water soluble nutrients directly to the root zone reducing losses through leaching or evaporation. Such a specific strategy enhances the efficiency of water- and nutrient-use, reduces the cost of inputs, and promotes sustainable production, especially in those regions where the water supply is limited.

The digital technologies and, in particular, the Internet of Things (IoT) have improved the precision growing systems to a considerable degree. IoT based platforms are also used to bring together sensors, controllers, and actuators to enable the free flow of information and automated

management of greenhouse activities. Mobile or web-based applications can assist growers in remotely tracking environmental conditions and adjusting irrigation and climate parameters, as well as notifying them about the deviation of the optimal ranges. This connectivity enhances decision-making, minimizes the amount of labor demanded and makes sure they respond to the possible stress factors in time. Decision-support systems (DSS) are very vital in transforming data into a reality in management strategies. DSS can give advice on how irrigation should be scheduled, the management of the nutrients, the optimization of the climate, and the protection of crops by analyzing both historical trends and real time information. These systems are of great importance in floriculture to synchronize flowering, schedule harvests and coordinate production to market need. The weather forecast and the crop growth models can also be incorporated in advanced DSS, which expands the prediction opportunities. In floriculture, the use of growing systems based on precision has gained a wider range of application due to the latest development in artificial intelligence and machine learning. Computer vision and image based monitoring methods are being adopted more often to measure plant growth, determine nutrient deficiency, and early infestation of pests and disease. The complex datasets can be used to predict yield, growth patterns, and stress response by using machine learning algorithms and apply proactive and targeted interventions. Such innovations help to minimize the consumption of chemicals and encourage production methods that are socially friendly to the environment. Another aspect that has a positive effect on environmental and economic sustainability is precision growing systems. Efficiency of input consumption decreases wastage, minimizes the production cost, and decreases the environmental pollution. The resource efficiency is improved and in combination with the quality of the flowers and stability of the yield make the produce more profitable and competitive in the market. Furthermore, precision systems contribute to the introduction of the integrated pest management and biological control practices under the safeguard of protected conditions.

**High-technology Soil-Less Cultivation**

Developed soilless growth systems have become a core of contemporary shielded floriculture,

where there is accurate control of the root-zone environment and most of the constraints of soil cultivation are eluded. Soilless systems do not use natural soil but instead grow plants in nutrient solutions or inert substrates thus reducing soil-borne diseases, increasing nutrient availability, and general crop performance. Soilless cultivation systems have become highly popular in horticulture, especially in the high-tech green house setting where uniformity, flower quality and production efficiency are important. One of the most common soilless cultivation methods that is widely used in floriculture is hydroponics. Plant roots are cultivated in this system itself in a nutrient-sustained water solution, which provides all the necessary macro- and micronutrients in easily accessible forms. Hydroponic systems enable the clear control of nutrient concentration, pH, and electrical conductivity, which leads to optimum nutrient uptake and high growth rate of plants. Often ornamental and cut flower crops are cultivated using techniques like nutrient film technique (NFT), deep water culture and ebb-and-flow. Hydroponics also guarantees efficient utilization of water because the nutrient solutions are frequently recirculated, thus it is very appropriate in areas that have scarce water resources.

Aeroponics is a more sophisticated practice of soilless farming; this technique involves the root of the plants being suspended in the air and occasionally sprayed with a fine spray of nutrient solution. This system gives good oxygen supply to the roots hence leading to increased nutrient uptake and faster growth levels. It has been demonstrated that aeroponics has promising outcomes in high-value floriculture crops because it enhances vigorous root growth and growth of the plants uniformly. Nevertheless, it is the technical complexity and increased capital cost of the aeroponic systems that restrict their use to the special and research-oriented floricultural businesses. Another new soilless method which is currently being applied in sustaining floriculture is called aquaponics and involves a combination of hydroponics and aquaculture. In this system, wastewater with high levels of nutrients that is produced during fish culture feeds plants and plants serve to clean up the water to be reused in fish tanks. Aquaponics is increasingly finding application in ornamental plant production even though it is more widely applied in vegetable production since it is eco-friendly and the nutrients have high level of

recycling. Aquaponics saves on using fertilizers that are synthetic, and it encourages circularity in resource utilization, which is sustainable.

The soilless cultivation systems based on the use of substrate are most commonly employed in the commercial floriculture because of the flexibility and their comparative simplicity to operate. The plants are cultivated in either inert or organic media like cocopeat, perlite, vermiculite, rockwool or a combination of the two. These substrates literally support the plants and at the same time, water and nutrient supply is well controlled with fertigation. Cocopeat based systems are more popular in the tropical areas, as they have a large water-retention ability, excellent aeration, and sustainability. The crops that are suitable in substrate based systems include rose, gerbera, carnation and chrysanthemum that are cultivated in a protected environment. One of the characteristics of soilless cultivation techniques is advanced nutrient management. The formulations of nutrients are personalized and made according to crop type, stage of growth and environmental factors. Automated fertigation systems allow proper and uniform supply of nutrients, reducing deficiencies and toxicities. The fact that nutrient solution parameters are continuously monitored allows one to make immediate changes that lead to the fact that crops are always functioning well, and the quality of their flowers is also high. The use of Soilless cultivation methods also has an important benefit in the management of pests and diseases. Lack of soil will minimize the occurrence of soil-borne pathogens and nematodes and minimizes the use of chemical treatments. There are clean and controlled root-zone environments, which promote the application of integrated pest management and biological control measures and help to achieve safer and environmentally friendly flower production.

**Conclusion**

The establishment of safeguarded floriculture especially the use of advanced technological green houses, precision growing apparatus, and the enhanced soilless cultivating methods have radically altered contemporary flower production. Such technological innovations mitigate most of the limitations that are related to traditional open-field floriculture as they are climatic uncertainty, inefficiency in resource utilization, and inconsistent quality. Protected floriculture

through the development of a regulated and streamlined growing system allows the production of high value flower crops all year round with higher uniformity, aesthetics and marketability. State of the art greenhouses have undergone an advancement to become advanced, computerized production facilities that can control temperature, humidity, light, carbon dioxide, and air flow in a highly precise way. The combination of automation, renewable energy solutions, and modern lighting technologies has enhanced the energy efficiency and minimized the environmental footprint of the floriculture enterprises. These structures are further complemented by precision growing systems, which can allow monitoring and controlling water, nutrients, and climate in real-time by means of sensor networks and Internet of Things platforms as well as decision-support systems. These technologies combined promote productivity and reduce the input wastage and risk production. More sophisticated soilless farming methods such as hydroponics, aeroponics, aquaponics and substrate-based systems have provided an additional layer to the field of protected floriculture because root-zone conditions may now be precisely controlled. These systems enhance nutrient absorption, decrease soil-borne diseases, and enhance faster and even growth of plants leading to high quality of flowers and increased yield per hectare. Their use of water, nutrients efficiently is in line with sustainability goals and climate resistant farming. The protection technology of floriculture has been proven to benefit many farmers, but the adoption of the technology is still being challenged due to high start-up, technical expertise among others and access to the skilled manpower especially among small and marginal growers. These limitations need to be met through concerted efforts on policy support, capacity building, research and extension. The government incentives, low-cost financing systems, and custom training may be significant in improving accessibility and adoption.

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