# Advancements and Innovations in Protected Cultivation

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Protected Cultivation practices is a cropping technique wherein the micro environment surrounding the plant body is controlled partially /fully as per plant need during their period of growth to maximise the yield and resource saving. Among these protecting cultivation practices, green houses /polyhouses, plastic low tunnels, pit nursery, mist chambers, shade nets and screen houses etc. is useful.

This technology has the potential to improve the availability of high-quality vegetables, flowers, and fruits in urban areas by lowering transportation time and providing fresh food. Greenhouses are structures made of transparent materials such as polythene or glass. The covering functions as a selective radiation filter, allowing shortwave solar light to pass but trapping long wave radiation. Because of its low transparency, long wave radiations released by plants and items in the greenhouse cannot flow through it. The trapped solar energy inside the greenhouse causes the temperature to rise. The increased temperature inside the greenhouse impacts leaf temperature, which influences leaf transpiration, stomatal aperture, and the plant's photosynthetic rate. The climatic control in the greenhouse can be used to change the physiological conditions of plants. Closing the greenhouse at night increases the $CO_2$ level due to plant respiration, which is then used for photosynthesis by the plants in the early morning hours of the following day. The rise in temperature, relative humidity, $CO_2$ levels, and improved nutrition under greenhouse conditions is responsible for rapid growth and greater yield.

Protected cultivation requires distinct management approaches compared to open field production. To accommodate the demand for fresh vegetables, strawberries, flowers, and fruit trees, multi-storey greenhouses in urban areas are necessary. Protected cultivation technologies include natural ventilation, polyhouses, drip irrigation, fertigation, and mulching. Walk-in polytunnels are beneficial for cultivating tomatoes, capsicum, and cucurbits and propagating nursery plants during the off season. Site selection is a key factor for profitable and sustainable greenhouse production. The main factors determining location and site selection of a greenhouse production area are: cost of production, quality of produced yield, and transportation cost to markets (Castilla, 2007). Other factors affecting greenhouse location are microclimate, Harsh weather conditions, Irrigation, Drainage, Pollution, Availability of space, Availability of labour, Infrastructures and Orientation (Salah and Azmi 2015).

**Types of Green Houses**

**Low-cost greenhouse/polyhouse:**

The low-cost polyhouse is made of 200 micron (800 gauge) transparent polythene sheet supported by bamboos, jute ropes, and nails. It is used to protect crops from heavy rainfall. The temperature inside a polyhouse rises by 6-10°C higher than outside. The UV stabilized plastic film-covered pipe-framed polyhouse has a greater daytime temperature than the exterior. The polyhouse receives 30-40% less solar radiation than the surrounding soil surface. During summer, open the sides of the greenhouse to regulate the temperature during the day.

**Medium-cost greenhouse/polyhouse**

The medium-cost greenhouse is slightly higher cost when compared to low-cost polyhouses. It is quonset-shaped and can be constructed with GI pipe (class B) of 15mm diameter. The structure is protected by a single layer of UV-stabilized polythene measuring 200 microns thick. Natural ventilation can be achieved by opening windows on the sides and roof, or exhaust fans can be employed. The fanpad system can humidify the polyhouse, lowering the temperature.

**High-cost greenhouse/polyhouse:**

It is constructed with iron/aluminium and has a dome or cone shape. Crop-specific temperature, humidity, and light levels are automatically regulated for optimal results. The floor and half of the side walls

are built of concrete. Although incredibly durable, it is around 5-6 times more expensive. This requires a qualified operator, adequate maintenance, and safeguards during operation.

**Classification of Polyhouses Based on Shape**

**Lean-to Greenhouses**: Lean-to greenhouses are attached to an existing building, such as a house, barn, or garage. They share one wall with the existing structure, which helps to provide thermal mass and may reduce construction costs.

Lean-to Greenhouses

**A-Frame Greenhouses**: A-frame greenhouses feature a distinctive roof design that slopes downward on both sides, resembling the letter "A". This design allows for efficient shedding of rain and snow, and it maximizes natural light penetration.

A-Frame Greenhouses

**Gothic Arch Polyhouses**: Gothic arch polyhouses feature a peaked roof with curved sidewalls, resembling the shape of a Gothic arch. This design provides additional headroom and allows for efficient shedding of snow and rainwater. Gothic arch polyhouses are suitable for taller crops and can withstand heavy snow loads.

Gothic Arch Polyhouses

**Quonset Greenhouses**: Quonset greenhouses have a rounded or semicircular shape, resembling a tunnel. They are often made of metal or PVC pipes covered with plastic sheeting. Quonset greenhouses are popular for their simplicity, cost-effectiveness, and

ability to withstand strong winds.

Quonset Greenhouses

**Ridge-and-Furrow Greenhouses**: Ridge-and-furrow

greenhouses consist of multiple connected bays or sections arranged in a straight line with a ridge along the top. This design maximizes space utilization and allows for efficient heating and ventilation systems.

Ridge and furrow

**Uneven span types green house**: This type of greenhouses is constructed on hilly terrains. The roofs are of unequal width, make the structure adaptable to the side slope of the hill**.**

**Even type greenhouses**: Even type greenhouses are also known as even-span greenhouses, are a type of greenhouse structure characterized by a uniform roof pitch and consistent height across the entire width of the structure. These greenhouses are designed to maximize interior space and optimize growing

conditions for crops. Here are some key features and advantages of even type greenhouses

Even type greenhouses

Uneven span types green house

**Functions of Green Houses**

**Temperature Regulation:** Greenhouses effectively trap solar radiation, creating a warmer environment than the external surroundings. This enables growers to extend the growing season, start crops earlier in the spring, and continue production later into the fall or even through the winter in some regions. Temperature regulation is vital for optimizing plant growth, as different crops have specific temperature requirements for germination, flowering, and fruiting.

**Humidity Control:** Greenhouses help to maintain optimal humidity levels for plant growth. The enclosed environment prevents rapid moisture loss, particularly in arid climates, while adequate ventilation prevents excess humidity that can lead to fungal diseases and rot.

**Protection from Extreme Weather:** Greenhouses shield plants from adverse weather conditions such as heavy rains, hailstorms, and strong winds, which can damage crops and reduce yields. They also provide protection against frost, allowing growers to cultivate sensitive crops that would otherwise be vulnerable to cold temperatures.

**Pest and Disease Management:** The enclosed nature of greenhouses acts as a physical barrier against pests such as insects, rodents, and birds, reducing the need for chemical pesticides. Additionally, the controlled environment enables growers to implement integrated pest management (IPM) strategies more effectively, utilizing biological controls and cultural practices to minimize pest damage.

**Optimized Growing Conditions:** Greenhouses allow growers to manipulate various environmental factors to create ideal growing conditions for specific crops. These factors include light intensity, photoperiod (day length), carbon dioxide levels, and air circulation. By fine-tuning these parameters, growers can optimize photosynthesis, improve crop quality, and increase yields.

**Resource Efficiency:** Greenhouses promote resource efficiency by minimizing water usage and fertilizer runoff. Drip irrigation systems and soilless growing mediums (e.g., hydroponics, aquaponics) deliver water and nutrients directly to plant roots, reducing wastage and maximizing efficiency. Moreover, the controlled environment allows for precise nutrient management, minimizing excess fertilizer application and environmental pollution.

**Research and Experimentation:** Greenhouses serve as invaluable research tools for plant scientists, breeders, and agronomists. They provide a controlled setting for conducting experiments on plant genetics, physiology, and cultivation techniques. Researchers can study the effects of environmental stressors, test new crop varieties, and develop innovative growing methods to enhance agricultural productivity and sustainability.

**Other protective structures**

**Plastic low tunnels**

Plastic low tunnels are simple structures at a height of 0.75-1.0m that protect plants from adverse climatic conditions and pest. For low tunnels, a 100-micron film is sufficient which costs approximately Rs.10-20 per square meter. These are used to cover seedling and individual growing beds in the field. Cladding materials can be removed during favourable weather conditions. Crops grown in polytunnels are Tomato, Cucumber, capsicum (coloured), red cabbage, radish, spinach, Gerbera, Gladiolus, rose, Chrysanthemum, Carnation , Sapota and Strawberry (Rahul & Arunabha 2020).

Plastic low tunnels

**Net houses**

Net houses are constructed at a height of 3 meter to cultivate vegetable and flower crops. The crop was covered with a shading net with a sufficient shade capacity (35-90% shade) and colour based on its needs. Low and medium-cost greenhouses are ideal for producing high-value crops and flowers during the rainy season (July-October). Vegetables including tomatoes, cherry tomatoes, coloured capsicum, cucumbers, and pole type French beans are challenging to grow in open conditions during this period. Due to their scarcity, these commodities command high market prices, enhancing profitability. Shade nets are of different types such as flat roofs, slopped roof, net tunnels.

Shade net

**Innovations in Protected Cultivations**

**Heating and cooling technologies**

In polyhouses, heating and cooling technologies often involve systems like radiant heaters and evaporative cooling pads to regulate temperatures. Ventilation and air circulation systems incorporate fans and vents to ensure proper air exchange, preventing heat buildup and humidity fluctuations. Humidity control mechanisms such as misting systems and automated vents help maintain ideal moisture levels for plant growth while preventing fungal diseases.

**Irrigation Techniques and Resource Efficiency**

Efficient water management is a cornerstone of sustainable agriculture, particularly in water-scarce regions. Protected cultivation enables precise control over irrigation practices, with techniques such as drip irrigation, fertigation, and hydroponics minimizing water wastage and nutrient runoff while promoting uniform plant growth and enhanced nutrient uptake. Furthermore, the integration of sensor-based irrigation systems and data analytics enables real-time monitoring of soil moisture levels, facilitating precise water delivery and resource optimization.

**Robotics in enclosed agriculture**

Protected cultivation is a high-risk, high-cost innovative strategy that only allows for the production of valuable crops. In recent years, agricultural technologies have attracted much attention in scientific research studies, and many attempts have been made for their development, particularly focused on the application of robots and automation on intensive crops. In particular, the application of robotics in protected agriculture would improve overall performance and production efficiency and also enhancing labour quality and safety. Robots can effortlessly do repetitive operations, replacing human labour, at the same time, can operate in a hazardous environment, significantly lowering human operators' exposure to risks, such as spraying chemicals and pesticides in protected farming (Giorgia *et. al*., 2022).

**Crops grown under protected cultivation**

High value vegetables like tomato, cherry tomato, coloured capsicum, parthenocarpy cucumbers, french beans (pole type), winter watermelon, muskmelon and strawberries can be grown successfully out of season under polyhouses/ walk-in tunnels in Northern India (Rahul and Arunabha 2020). The technology has also been proved valuable to produce grafted fruit plants year-round.

## Conclusion

Protected cultivation represents a paradigm shift in modern agriculture, offering a sustainable approach to meet the growing demand for food while minimizing environmental impact. Continued research and innovation are essential to address existing challenges and unlock the full potential of protected cultivation systems. By embracing advancements in technology, adopting sustainable practices, and fostering interdisciplinary collaborations, stakeholders can propel protected cultivation towards a more resilient and resource-efficient future. With the high adoption of protected cultivation, there's continuous new development in agriculture crops analysis and production and development within the connected industries (Kang et al., 2013).

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