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Tomato Cultivation under Protected Structures: Enhancing Yield and Quality

*Dr. M. Kabilan
Regional Coffee Research Station, Coffee Board, Thandigudi, Tamil Nadu, India
*Corresponding Author's email: kabimathi21@gmail.com

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops cultivated worldwide due to its high nutritional value, economic importance and versatility in culinary applications. It is a rich source of vitamins A and C, potassium and bioactive compounds such as lycopene, which possess antioxidant and anticancer properties. In India, tomato plays a crucial role in the vegetable economy; however, its productivity is often limited by climatic variability, pest and disease pressure and inefficient resource management under open-field conditions. In recent years, protected cultivation has emerged as an innovative approach to overcome these limitations by providing a controlled environment that enhances crop growth, yield and quality. Protected structures such as polyhouses, greenhouses and shade net houses allow regulation of temperature, humidity, light and carbon dioxide concentration, thereby creating optimal conditions for tomato cultivation throughout the year.

Importance of Protected Cultivation in Tomato

Protected cultivation offers numerous advantages over conventional open-field farming. It enables year-round production, protects crops from adverse weather conditions such as heavy rainfall, frost and extreme temperatures and reduces pest and disease incidence. The controlled environment improves water and nutrient use efficiency, resulting in higher productivity and superior fruit quality. Yield under protected conditions can reach 100–250 tonnes per hectare compared to 25-40 tonnes per hectare in open-field cultivation. Additionally, fruits produced under protected systems are uniform in size, shape and color, with improved shelf life, making them suitable for high-value markets and export.

Types of Protected Structures

Protected cultivation of tomato can be carried out in different types of structures depending on the level of environmental control and investment capacity. Polyhouses are the most commonly used structures, covered with polyethylene sheets that help maintain temperature and humidity. Greenhouses are advanced structures equipped with automated systems for precise control of environmental parameters such as temperature, humidity and ventilation. Shade net houses provide partial protection and are mainly used for nursery raising and low-cost cultivation. The choice of structure depends on climatic conditions, crop requirements and financial resources.

Climatic Requirements under Protected Conditions

Tomato is a warm-season crop that requires an optimum temperature range of 18-28°C for growth and development. Temperatures above 35°C or below 10°C adversely affect flowering and fruit set. Relative humidity of 60-70% is ideal, as excessive humidity can promote fungal diseases, while low humidity may lead to flower drop. Adequate light intensity is essential for photosynthesis and fruit development. Protected structures allow the

regulation of these parameters, ensuring optimal conditions for plant growth and maximizing yield potential.

Selection of Varieties and Hybrids

The success of tomato cultivation under protected structures largely depends on the selection of suitable hybrids. Indeterminate hybrids are preferred as they produce fruits over a longer duration and are suitable for vertical training systems. Ideal hybrids should possess high yield potential, resistance to major diseases such as tomato leaf curl virus, Fusarium wilt and bacterial wilt and desirable fruit quality traits such as uniform size, firmness and longer shelf life. Popular hybrids such as Arka Rakshak, Arka Samrat, NS 4266, Heem Sohna and Naveen 2000+ have shown excellent performance under protected conditions.

Nursery Management

Nursery management is a critical step in achieving successful crop establishment. Seeds are sown in pro-trays filled with soilless media such as cocopeat, vermiculite and perlite, which provide good aeration, water retention and nutrient availability. Seed treatment with fungicides or biological agents helps prevent seed-borne diseases and enhances germination. Seedlings are grown under controlled conditions with optimal temperature and moisture and are ready for transplanting within 25-30 days. Healthy and vigorous seedlings ensure better establishment and higher productivity.

Land Preparation and Transplanting

Proper land preparation is essential for root development and nutrient uptake. Raised beds of about 1 meter width and 30 cm height are prepared inside the protected structure. Soil should be well-drained, fertile and rich in organic matter. Spacing of 45-60 cm between plants is maintained to ensure adequate aeration and light penetration. The use of plastic mulch helps conserve moisture, control weeds and regulate soil temperature. Transplanting is done carefully to avoid root damage and ensure quick establishment.

Training and Pruning

Training and pruning are important cultural practices in protected tomato cultivation. Plants are trained vertically using a trellis system to support growth and maximize space utilization. Pruning involves the removal of side shoots or suckers to maintain a single or double stem system. This practice improves light interception, air circulation and nutrient allocation, resulting in better fruit quality and reduced disease incidence.

Irrigation and Fertigation Management

Efficient irrigation and nutrient management are crucial for achieving high yields under protected conditions. Drip irrigation is commonly used, as it provides water directly to the root zone and reduces wastage. Fertigation, the application of fertilizers through irrigation water, ensures precise and uniform nutrient supply. The nutrient requirement varies with growth stages, with higher nitrogen during vegetative growth and increased potassium during fruiting to improve fruit quality. Micronutrients such as calcium, magnesium and boron are also essential for preventing physiological disorders.

Pollination Management

Pollination is often limited in protected structures due to the absence of natural pollinators and restricted air movement. To enhance fruit set, manual shaking of plants or the use of bumblebees is practiced. Proper pollination ensures uniform fruit development and higher yield.

Pest and Disease Management

Protected cultivation reduces the incidence of pests and diseases; however, certain pests such as whiteflies, aphids and thrips can still cause significant damage. These pests also act as vectors for viral diseases such as tomato leaf curl virus. Integrated pest management (IPM) practices, including the use of insect-proof nets, sticky traps, biological control agents and need-based application of pesticides, are essential for effective control. Diseases such as powdery mildew, Fusarium wilt and bacterial wilt can be managed through resistant varieties, proper sanitation and environmental control.

Harvesting and Yield

Tomato plants start yielding within 70-90 days after transplanting under protected conditions. Fruits are harvested at different maturity stages depending on market requirements. For local markets, fully ripe fruits are preferred, while for distant markets, fruits are harvested at the breaker stage. Yield under protected cultivation can reach up to 250 tonnes per hectare, which is significantly higher than open-field production.

Post-Harvest Management

Post-harvest handling plays a crucial role in maintaining fruit quality and reducing losses. Fruits are sorted, graded and packed in suitable containers to prevent mechanical damage. Storage at temperatures of 12-15°C helps extend shelf life and maintain quality. Value addition through processing into products such as ketchup, puree and sauces can further enhance profitability.

Economic Analysis

Protected cultivation requires high initial investment for the construction of structures, irrigation systems and inputs. The cost of establishing a polyhouse ranges from ₹25 to 40 lakh per hectare. However, the high yield and superior quality produce result in higher returns, with gross income ranging from ₹50 to 80 lakh and net profit of ₹20 to 35 lakh per hectare. Government subsidies and financial support schemes can help reduce the financial burden on farmers.

Constraints and Challenges

Despite its advantages, protected cultivation faces several challenges, including high capital investment, requirement for technical expertise and risk of pest outbreaks within enclosed structures. Market price fluctuations and lack of proper marketing infrastructure can also affect profitability. Proper training, technical support and market linkages are essential to overcome these challenges.

Future Prospects

The future of tomato cultivation under protected structures is promising, with advancements in technology such as automation, sensors, artificial intelligence and hydroponics. Precision farming techniques and climate-smart practices can further enhance productivity and sustainability. Integration of renewable energy sources and efficient resource management strategies will play a crucial role in the widespread adoption of protected cultivation.

Conclusion

Tomato cultivation under protected structures represents a significant advancement in modern horticulture, offering a viable solution to the challenges of open-field farming. By providing a controlled environment, it enhances yield, quality and resource use efficiency while ensuring year-round production. The adoption of improved hybrids, efficient irrigation and fertigation

systems, integrated pest management practices and modern technologies can further increase productivity and profitability. Despite the challenges associated with high initial investment and technical complexity, the long-term benefits of protected cultivation make it a sustainable and profitable option for farmers. With increasing demand for high-quality vegetables and changing climatic conditions, protected cultivation will play a pivotal role in ensuring food security and improving farmers' livelihoods.

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