PROTECTED CULTIVATION IN VITICULTURE

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ABSTRACT: The grapevine (*Vitis* spp.) is one of the most economically significant fruit crops in Brazil, standing out in the fruit production sector for both domestic consumption and export. Among the innovative practices used to enhance production, protected cultivation has proven to be a promising technique in both emerging and traditional viticultural regions. This technique enables grapevines to express their maximum productive and qualitative potential by partially controlling environmental conditions such as temperature, humidity, and solar radiation. The use of plastic covers in protected cultivation systems minimizes plant exposure to adverse climatic factors, such as rainfall and dew, which often contribute to the formation of microclimates favorable to the proliferation of phytopathogenic agents, including fungi and bacteria. In addition to significantly reducing disease incidence, this system decreases the need for chemical pesticides, promoting a more sustainable and environmentally friendly production system that is also safer for consumers. Although the initial cost of implementing protected cultivation is high, it is offset by a rapid economic return, justified by the reduced use of inputs, increased management efficiency, and superior grape quality, which commands higher market prices. Thus, protected cultivation systems not only improve productivity but also meet the demands of an increasingly discerning consumer market regarding quality and food safety.

INTRODUCTION

Brazilian viticulture, encompassing the production of table grapes, juices, and wines, has undergone significant transformations driven by technological advancements and new management practices. Factors such as rising labor costs, high expenditures on phytosanitary products, increasing land prices, and growing consumer demands for high-quality products have intensified the search for more sustainable, efficient, and profitable cultivation systems. Grapevine cultivation, in turn, requires a high level of technical expertise to ensure fruit with desirable commercial characteristics, making protected cultivation one of the innovative approaches to achieving this goal (Kishino et al., 2007; Hernandes; Martins, 2008).

In countries such as Spain, Italy, France, Japan, and the United States, the use of protected cultivation systems is well established (Sentelhas; Santos, 1995; Mota et al., 2009). These structures provide greater control over environmental conditions, contributing to improved grape quality and adding value to the final product (Lulu, 2005). In Brazil, the adoption of plastic covers over vineyards has grown significantly in recent years, serving as an effective alternative to mitigate adverse climatic impacts such as excessive rainfall and dew, which promote fungal disease development. Reducing free water on leaves and grape clusters decreases the need for chemical spraying, increasing sustainability and lowering operational costs throughout the production cycle (Tagliari, 2003; Lulu et al., 2005; Chavarria et al., 2007a).

The protected environment modifies essential microclimatic variables such as temperature, solar radiation, wind speed, and relative humidity, creating more favorable conditions for grapevine physiological development (Cardoso et al., 2008). These changes can mitigate water and thermal stress, promoting vigorous plant growth and improving both productivity and fruit quality (Chavarria et al., 2008). Despite its evident benefits, protected cultivation requires a high initial investment, particularly in materials such as plastic covers and shade nets. The lifespan of plastic covers ranges from three to four years (Heckler, 2009), whereas plastic screens, widely used in the São Francisco Valley and northwestern São Paulo, have greater durability, lasting up to 10 years (Pires; Martins, 2003).

Several studies have demonstrated the benefits of protected cultivation in viticulture, including improvements in fruit quality, increased production, pest and disease control, and physical protection against weather adversities such as wind, hail, frost, and rain (Lulu et al., 2005; Detoni et al., 2007; Chavarria et al., 2007a; Chavarria et al., 2007b; Chavarria et al., 2010). In this context, this literature review aims to highlight the importance of protected cultivation in Brazilian viticulture, emphasizing gains in productivity and quality, as well as discussing the types of covers available and their implications for vineyard management and system implementation.

STRUCTURES USED IN PROTECTED CULTIVATION

With the advent of the petrochemical industry in the 1930s, plastic materials became widely utilized across various sectors, including agriculture. Plastic films rapidly emerged as innovative components in plant production systems and, more recently, have gained prominence in viticulture, being employed in both table grape cultivation and the production of juice and wine grapes.

Currently, two primary types of agricultural plastics are utilized for vineyard coverage: impermeable plastic fabric and extruded smooth plastic, both composed of polyethylene. The plastic fabric is distinguished by its superior tensile strength, making it particularly suitable for areas subject to strong winds and adverse climatic conditions, whereas smooth plastic is more commonly used due to its lower cost. To enhance field longevity and efficiency, plastics may be treated with specific additives, such as ultraviolet (UV) stabilizers, which prevent material degradation induced by prolonged solar exposure, and anti-drip agents, which inhibit the formation of condensation droplets on the inner surface of the cover, thereby mitigating disease incidence. However, the lifespan of these materials can be compromised by catalytic oxidation, triggered by metal residues from agrochemicals or support structures, including copper, iron, and sulfur, which progressively induce opacity and structural fragility.

The structural configurations for implementing protected cultivation systems vary according to local environmental conditions and producer demands, necessitating adaptations to optimize system efficacy. The most frequently employed structures include greenhouses, high tunnels, protective arches, and shade net coverings. Greenhouses, which are typically enclosed, enable comprehensive microclimatic regulation and are extensively utilized in regions subject to extreme climatic variability.

High tunnels and protective arches, conversely, represent more cost-effective alternatives that facilitate enhanced ventilation and reduced internal humidity, rendering them well-suited for high-precipitation regions. Shade net coverings, constructed from black or white polymeric meshes, provide shielding against excessive solar radiation and exhibit extended durability, with a lifespan of up to ten years. These structures not only safeguard vineyards against abiotic stressors but also establish an optimized microenvironment for vine physiological processes, contributing to increased productivity, improved fruit quality, and enhanced sustainability within viticultural systems.

BENEFITS OF PROTECTED CULTIVATION

Protected cultivation has been established as an innovative technique in viticulture due to its numerous benefits in terms of productivity, fruit quality, and sustainability. The microclimatic modifications induced by plastic covers allow grapevines to express their maximum productive potential, resulting in significant gains in both yield and grape quality. The creation of a more controlled environment contributes to uniform plant growth, proper cluster development, and the production of berries with higher sugar concentrations, intense coloration, optimal texture, and lower defect rates-highly desirable characteristics for the market.

One of the primary benefits associated with the use of plastic covers is the reduction of adverse climatic impacts. These structures protect grapevines from excessive rainfall, hail, dew, and strong winds, which can cause physical damage to leaves and clusters, promote disease onset, and compromise productivity. By limiting direct contact with water, particularly during critical developmental stages, protected cultivation prevents the formation of microclimates conducive to pathogen establishment, such as fungi responsible for downy mildew, powdery mildew, and fruit rots.

Another key advantage is the reduction in the use of agricultural pesticides, yielding both economic and environmental benefits. Under protective covers, the lower incidence of fungal diseases and pest infestations decreases the need for frequent chemical applications, reducing production costs and minimizing agriculture's environmental footprint. This aspect makes protected cultivation a more sustainable practice, addressing the growing demand for agricultural systems that combine production efficiency with environmental conservation.

Furthermore, protected cultivation enhances the quality of harvested grapes, adding commercial value to the final product. Grapes grown under this system exhibit greater uniformity, fewer physical defects, and a more appealing appearance—critical factors for the fresh grape market and the production of premium wines and juices. This improvement in quality not only increases the competitiveness of these products in the domestic market but also facilitates entry into more demanding international markets. Thus, protected cultivation represents an effective strategy for advancing modern viticulture, integrating high productivity, sustainability, and excellence in the final product.

PRODUCTIVITY GAINS AND QUALITY IMPROVEMENT

The use of plastic film allows grapevines to reach their maximum productive potential, leading to yield increases that can exceed 100% compared to conventional cultivation systems. This productivity gain is largely attributed to the protection offered by plastic films against precipitation during the flowering period, preventing fruit abortion, and to their photoselective capacity, which enhances the transmission of a greater amount of radiation. This increased light incidence promotes vegetative development, increases cluster weight, elevates soluble solids content (°Brix), and enhances the organoleptic characteristics of the fruit (López-Miranda, 2002).

Beyond direct productivity gains, protected cultivation significantly reduces the need for agricultural pesticides. In vineyards without plastic film, an average of 80 annual spray applications is required for disease control, a number that can be reduced to fewer than 15 under protected cultivation, representing up to an 80% reduction in pesticide use (Chavarria et al., 2007a; Colombo, 2010).

Grape quality is also enhanced by the use of plastic film. The fruit exhibits longer and heavier clusters with a higher number of berries per cluster, which are larger and heavier due to optimized turgor pressure facilitated by improved water availability in the protected environment. These factors are associated with higher soluble solids content and lower titratable acidity, contributing to superior sensory attributes (Antonacci; Tomasi, 2001; Ferreira et al., 2004). Additionally, the high light diffusion provided by plastic film protects leaves and fruit from burns caused by excessive direct radiation, promoting a more uniform and intense coloration-an essential attribute for commercial value, particularly for table grapes.

Another critical aspect is the temporal management of production enabled by protected cultivation. Studies indicate that applying plastic film before pruning accelerates dormancy break, advancing budburst and, consequently, fruit production (Novello; Palma, 2008). Conversely, using plastic film from the onset of ripening can delay fruit development, allowing for harvest postponement. In both scenarios, protected cultivation facilitates harvest scheduling, enabling producers to optimize harvesting times in alignment with market demand (Roberto et al., 2011).

EFFECTS OF PROTECTED CULTIVATION ON MICROCLIMATE AND PEST AND DISEASE CONTROL

Protected cultivation provides significant benefits in regulating climatic factors such as temperature, relative humidity, and solar radiation. These modifications influence the phenological cycle of grapevines, creating more favorable conditions for plant development. Additionally, the reduction in leaf wetness limits the proliferation of pathogens. In integrated management systems, coordinated strategies are implemented to control pests and diseases more efficiently, maximizing plant health and overall crop productivity.

These environmental modifications exert a direct impact on the grapevine's phenological cycle, affecting critical stages such as budburst, flowering, and fruit ripening. The reduction in rainfall incidence and the modulation of radiation, enabled by plastic covers, contribute to more uniform and synchronized plant development. This consistency facilitates cultural management and allows for more precise planning of field operations, resulting in a more stable and high-quality production system.

A major advantage of protected cultivation is the reduction of leaf wetness, which significantly limits the formation of humid microenvironments that favor pathogen development. With less water accumulation on leaves and grape clusters, the incidence of fungal diseases such as downy mildew and powdery mildew is considerably lower, promoting overall vineyard health and reducing the need for chemical applications.

Furthermore, the implementation of integrated management strategies enhances the benefits of protected cultivation. These strategies involve continuous environmental monitoring, the judicious use of plant protection products, and the adoption of practices that support sustainable pest and disease control. This comprehensive approach enables a more efficient and cost-effective production system while preserving environmental sustainability, ensuring maximum productivity and fruit quality.

ECONOMIC ASPECTS OF PROTECTED CULTIVATION

The adoption of protected cultivation in viticulture requires a high initial investment, primarily due to costs associated with support structures, the acquisition and installation of plastic covers, and ongoing maintenance throughout production cycles. However, this technology offers an attractive economic return in the medium and long term, driven by increased productivity, improved fruit quality, and higher commercial value of grapes. The ability to schedule harvests strategically and supply fruit during key market periods also enhances the system's profitability.

A significant economic advantage is the reduction in agricultural input costs, particularly those related to chemical pesticides. Compared to conventional cultivation, protected cultivation minimizes the need for frequent spraying, lowering operational expenses and reducing environmental impacts. Additionally, the decreased incidence of crop losses due to adverse weather conditions and diseases results in a more efficient harvest with less waste, optimizing production utilization and enhancing producer competitiveness.

Although the implementation cost may pose an initial challenge, financial returns are achieved within a few production cycles, depending on market conditions and the efficiency of the management practices adopted. Investing in protected cultivation thus becomes a viable strategy for producers seeking greater production stability, improved market positioning, and enhanced long-term economic sustainability.

FINAL CONSIDERATIONS

Protected cultivation represents a promising strategy for viticulture, significantly enhancing fruit quality, productive yield, and the sustainability of the production system. The use of plastic covers substantially reduces the incidence of fungal diseases, minimizing the need for pesticide applications and contributing to the reduction of environmental impacts. Furthermore, the microclimatic modifications resulting from this technology allow for more efficient control of environmental variables, promoting grapevine phenological development and ensuring a more uniform production with higher commercial value.

The ability to schedule harvests under protected cultivation offers greater flexibility in fruit supply, enabling product availability during strategic market periods, which can maximize producer profitability. However, the economic viability of this technology is directly linked to a cost-benefit analysis, which must consider factors such as initial investment, structural durability, and the edaphoclimatic conditions of the region. In this regard, the adaptation of cultivars to the protected environment and the assessment of grapevine physiological responses to this technique are fundamental aspects for consolidating protected cultivation as an efficient and sustainable model for viticulture.

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