3 Conventional Control Methods in Grapevine Protection

3.1 Chemical control strategies

In grape production, chemical control has long been the core strategy for managing pests and diseases, particularly in the control of downy mildew, powdery mildew, and major insect pests. Commonly used fungicides include protective compounds such as copper- and sulfur-based products, as well as systemic or translaminar fungicides such as strobilurins, triazoles, and SDHI fungicides, which are typically applied at fixed intervals throughout the growing season (Pertot et al., 2017; Pennington et al., 2018; Moine et al., 2023). Insect control is generally implemented when pest populations exceed economic thresholds, using organophosphates, neonicotinoids, pyrethroids, and some newer selective insecticides to manage key pests such as grape moths and disease-transmitting leafhoppers (Mwaka et al., 2024; Pavan et al., 2026). Under intensive cultivation systems, multiple pesticide applications are required within a single growing season to maintain yield and fruit quality.

However, frequent and preventive chemical applications also bring several problems. First, the risk of resistance development increases. After long-term repeated use, single-site fungicides have already selected for resistant populations in pathogens causing downy mildew and powdery mildew, as well as in some insect pests, thereby reducing the effectiveness of these chemicals (Toffolatti et al., 2024; Kaya et al., 2025). Second, pesticide residue issues have attracted increasing attention. Residues not only affect the food safety of grapes, grape juice, and wine, but may also impact non-target organisms and fermentation-related microbial communities, thereby indirectly influencing wine quality (Liviz et al., 2025).

3.2 Cultural and agronomic practices

Agronomic and cultivation management constitute an important foundation of traditional grape protection systems. Their main purpose is to reduce primary inoculum sources and suppress the occurrence of diseases and pests by improving the vineyard microclimate. Pruning, shoot training, and canopy management can improve air circulation and light penetration, thereby reducing canopy humidity and limiting the development of diseases such as downy mildew, powdery mildew, and gray mold (Pertot et al., 2017; Testempasis et al., 2023). At the same time, the timely removal of infected branches, mummified clusters, and weed hosts within the vineyard can effectively reduce overwintering pathogens and the sources of primary infection in the following growing season. In recent years, the concept of “proper pruning” has also emphasized minimizing large wounds and protecting sap flow pathways in order to maintain the long-term health of the vine (Mondello et al., 2017).

Soil, water, and nutrient management also directly affect grape resistance and disease pressure. Cover crops, green manure, and soil surface management can improve soil structure, enhance water infiltration, and increase soil microbial diversity, thereby strengthening plant stress resistance (Perria et al., 2022). In contrast, excessive nitrogen application can lead to excessive vegetative growth and dense canopies, increasing vineyard humidity and consequently aggravating fungal diseases and the risk of cluster rot (Pavan et al., 2026). In addition, proper irrigation, timely water regulation, and practices such as leaf removal and fruit thinning can help reduce cluster rot and the probability of pathogen colonization, thereby improving the overall effectiveness of disease control (Testempasis et al., 2023).

3.3 Physical and mechanical control

Physical and mechanical methods provide additional, often pesticide-free, tools for managing grapevine pests and can be readily integrated into conventional programs. Traps, particularly pheromone traps, are widely used for monitoring grape moth flights and can guide the timing of insecticide applications, thereby reducing unnecessary sprays (Pertot et al., 2017; Pennington et al., 2018; Pavan et al., 2026). In some settings, mass trapping or attract-and-kill devices contribute to direct suppression of pest populations, although these techniques are generally more effective when pest pressure is moderate and landscapes are relatively isolated (Pertot et al., 2017; Pavan et al., 2026). Physical barriers such as insect-proof nets or inter-row ground covers can prevent some insects from entering the canopy, but large-scale structural modification of vineyards is often limited by economic costs and landscape conservation requirements, especially in traditional European wine-growing regions (Pertot et