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An Integrated, Systems-Based Approach for the Sustainable Management of the Vine Mealybug (*Planococcusficus*) in the Vineyards of Nasik, Maharashtra

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Abstract: *Viticulture in Nasik, Maharashtra, is a cornerstone of the Indian wine and table grape industry, but its productivity is consistently threatened by the vine mealybug, Planococcusficus. This pest causes direct damage by feeding on phloem sap and indirect damage by vectoring viruses and promoting sooty mold growth via honeydew excretion. Over-reliance on broad-spectrum insecticides has led to documented resistance, secondary pest outbreaks, and environmental concerns. This paper synthesizes a decade of advancements in Integrated Pest Management (IPM) to propose a robust, multi-tactic strategy tailored for Nasik's agro-ecosystem. The proposed framework is built on a foundation of intensive scouting and monitoring using pheromone traps and visual inspection to establish action thresholds. Key management components include: 1) Cultural Controls: Proactive canopy management for improved aeration and spray penetration, along with rigorous ant exclusion protocols, a critical factor for enabling natural enemy success. 2) Biological Control: Augmentative releases of the predatory beetle Cryptolaemusmontrouzieri, whose efficacy is well-established in Indian conditions, and conservation of the parasitoid wasp Anagyruspseudococci. 3) Behavioural Control: Deployment of species-specific pheromones for mating disruption to reduce reproductive success. 4) Biopesticides: Timely application of entomopathogenic fungi and botanical insecticides, targeting the vulnerable crawler stage. 5) Judicious Chemical Intervention: Use of insect growth regulators and targeted systemic insecticides, like spirotetramat, as a final recourse, preserving beneficial insect populations. The synergistic integration of these tactics offers a sustainable pathway to suppress P. ficus populations below economic injury levels, reducing chemical residues, enhancing vineyard biodiversity, and ensuring the long-term viability of viticulture in the region.*

Keywords: Integrated Pest Management (IPM), *Vitis vinifera*, Vine Mealybug, *Planococcusficus*, Biological Control, Sustainable Viticulture, Pheromone Traps, Nasik

I. INTRODUCTION

The Nasik district in Maharashtra, often referred to as the "Wine Capital of India," is a region of immense viticultural significance. The unique semi-arid climate is conducive to the cultivation of high-quality table and wine grapes (*Vitis vinifera* L.). However, this intensive monoculture system is highly susceptible to pest pressure. Among these, the vine mealybug, *Planococcusficus* (Signoret), has emerged as one of the most economically damaging and difficult-to-control pests in the region (Sharma et al., 2014).

The insidious nature of *P. ficus* makes it a formidable challenge. Its cryptic habit, residing under bark, in clusters, and on roots, shields it from contact insecticides (Daane et al., 2012). The pest’s waxy, hydrophobic cuticle further reduces the efficacy of chemical sprays. Direct damage results from the extraction of plant sap, leading to reduced vigour and leaf drop. The indirect damage is often more severe; the excretion of copious amounts of honeydew provides a substrate for sooty mold, which inhibits photosynthesis and renders fruit unmarketable. Most critically, *P. ficus* is a competent vector of Grapevine Leafroll-Associated Viruses (GLRaVs), which cause a devastating decline in vine health, yield, and wine quality (Gutierrez et al., 2008).

Historically, management in many viticultural regions, including India, has been heavily reliant on a calendar-based application of broad-spectrum organophosphates and neonicotinoids. This approach is unsustainable. Extensive research has demonstrated that this strategy leads to the development of insecticide resistance (Prabhaker et al., 2011), the destruction of natural enemy populations, and secondary pest outbreaks (Daane et al., 2012). Furthermore, concerns over maximum residue limits (MRLs) for export markets necessitate a paradigm shift.

Integrated Pest Management (IPM) offers a scientifically sound, ecosystem-based alternative. Modern IPM is a holistic strategy that integrates multiple control tactics to manage pest populations below the Economic Injury Level (EIL). This paper synthesizes key findings from highly cited viticultural research to structure a comprehensive IPM program for *P. ficus* specifically adapted for implementation in the vineyards of Nasik, building on successful programs validated both globally and within India (Sawant et al., 2012).

II. MATERIALS AND METHODS

This study outlines a management framework derived from a synthesis of peer-reviewed literature. The methods described are not from a single field experiment but represent a consolidated strategy based on established and validated best practices.

2.1. Study System and Target Pest

The proposed framework is designed for the commercial vineyards of Nasik, Maharashtra. The target organism is the vine mealybug, *Planococcusficus*, at all life stages.

2.2. IPM Component Framework

- **2.2.1. Monitoring and Scouting:** The foundation of the IPM program is systematic data collection. This involves weekly visual inspections and the deployment of delta traps baited with the species-specific sex pheromone for *P. ficus*. Trap catch data, combined with visual detection, is used to determine action thresholds, a core principle of IPM (Daane et al., 2012).
- **2.2.2. Cultural and Mechanical Control:** This involves proactive viticultural practices. Methods include post-harvest removal of loose bark to eliminate overwintering sites. Canopy management, such as leaf removal, is crucial to increase air circulation and improve the penetration of control agents. A critical component is ant management. Ants protect mealybugs from natural enemies in exchange for honeydew, and their control is often a prerequisite for successful biological control (Walton et al., 2009).
- **2.2.3. Biological Control:** The strategy emphasizes an inoculative and augmentative approach. This involves the timed release of the predatory lady beetle *Cryptolaemusmontrouzieri*, whose bio-efficacy against grape mealybugs has been successfully demonstrated under Indian field conditions (Mani et al., 2011). Concurrently, conservation of naturally occurring parasitoids, such as *Anagyruspseudococci*, is promoted by avoiding broad-spectrum insecticides (Biondi et al., 2012).
- **2.2.4. Behavioral Control:** Mating disruption is a powerful, species-specific tactic. It involves saturating the vineyard with the synthetic female sex pheromone, preventing males from locating females and thereby suppressing reproduction. The efficacy of this technique is highly dependent on dispenser density and vineyard layout (Walton et al., 2006).

- **2.2.5. Biologically-Based Pesticides:** When monitoring indicates that populations are approaching action thresholds, biopesticides are the first line of spray intervention. Formulations containing entomopathogenic fungi like *Lecanicilliumlecanii* or *Beauveriabassiana* are applied, primarily targeting the mobile crawler stage.
- **2.2.6. Judicious Chemical Intervention:** The use of synthetic conventional insecticides is a last resort. Chemical selection is based on efficacy and selectivity. Systemic products like spirotetramat and insect growth regulators (IGRs) like buprofezin are preferred for their effectiveness against mealybugs and reduced impact on beneficial insects. Recent field trials in India have confirmed the high efficacy of these modern chemistries against *P. ficus* (Satish Kumar et al., 2017).

III. RESULTS AND DISCUSSION

The implementation of the synthesized IPM program is projected to yield significantly superior and more sustainable results compared to a conventional, insecticide-based schedule.

Synergy of Multiple Tactics: The strength of this IPM program lies in the synergistic interaction of its components. For instance, effective ant management is not just a cultural control but a critical enabler of biological control; without it, predators are often unable to access mealybug colonies (Walton et al., 2009). Similarly, canopy management improves spray coverage for both biopesticides and selective chemicals.

From Reaction to Prevention: The foundation of pheromone trapping and scouting shifts the management paradigm from reactive to proactive. Mating disruption further enhances this preventative model by suppressing the population's reproductive potential from the outset (Walton et al., 2006). This data-driven approach significantly reduces the number of insecticide applications, lowering costs and mitigating the risk of resistance development, a known issue with older chemistries (Prabhaker et al., 2011).

Harnessing and Conserving Vineyard Ecology: The program actively leverages ecosystem services. By releasing *C. montrouzieri* which is a predator proven effective in Maharashtra (Mani et al., 2011), and conserving native parasitoids (Biondi et al., 2012), the vineyard itself becomes a less hospitable environment for the mealybug. This biological buffer provides continuous, season-long suppression, making the vineyard more resilient.

The Evolving Role of Insecticides: This framework redefines the role of insecticides as precision tools rather than blunt instruments. The use of "softer," selective chemistries is crucial. Studies conducted in India have shown that molecules like spirotetramat, thiamethoxam, and buprofezin provide excellent control of *P. ficus* when timed correctly (Satish Kumar et al., 2017). By targeting the vulnerable crawler stage, these applications are maximally effective.

Challenges and Adoption in Nasik: The successful adoption of this comprehensive IPM strategy in Nasik depends on farmer education and a supportive infrastructure for the supply of biocontrol agents and pheromones. However, the long-term benefits are substantial. Validation studies in India have already demonstrated that an IPM module for grapes can effectively manage mealybugs, reduce pesticide residues, and be economically viable for farmers (Sawant et al., 2012). Given the pest's significant presence in the region (Sharma et al., 2014) and its role as a virus vector (Gutierrez et al., 2008), adopting a robust IPM program is not merely an option but a necessity for the sustainable future of viticulture in Nasik.

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