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EFFECTIVE PLANT VIRUS MANAGEMENT INTEGRATES STRATEGIES TO PROTECT AND SUSTAIN CROP HEALTH

Effective plant virus management is paramount for ensuring sustainable crop production and global food security. This review article delves into integrated strategies to mitigate the impact of plant viruses on crops, underscoring the necessity of a multifaceted and comprehensive approach to virus control. The primary objective of this research is to synthesize current knowledge on plant virus management, emphasizing the synergistic application of biological, chemical, and cultural practices. The core focus of the study involves evaluating the efficacy of these strategies both individually and in combination to formulate a robust and holistic management plan. The study underscores the scientific importance of integrating diverse methodologies, which not only mitigate virus incidence but also bolster overall crop resilience, yield, and long-term sustainability. The methodology entails a critical and exhaustive analysis of existing literature, appraising the outcomes of various virus management strategies across different crops, regions, and environmental contexts. Key findings reveal that integrated management approaches, such as deploying resistant cultivars alongside crop rotation and precision-targeted pesticide application, markedly diminish virus transmission, severity, and associated impacts. The research concludes that a holistic strategy for plant virus management is indispensable for securing long-term crop health, stability, and productivity. This work significantly contributes to the field by providing a comprehensive synthesis of effective management *practices, establishing a solid framework for future research and practical application. The practical implications lie in the potential to implement these integrated strategies across diverse agricultural systems, ultimately fostering more sustainable crop production, enhanced food security, and reduced economic losses due to plant viruses.*

Keywords: Virus Management, Integrated Strategies, Crop Resilience, Sustainable Agriculture, Virus Control, Monitoring, Plant Immunity, Biosecurity.

Introduction

Plant viruses represent a profound threat to sustainable agriculture, leading to substantial economic repercussions. The advent of novel viral diseases is predominantly driven by global trade, climate fluctuations, and the rapid adaptive evolution of viruses. Effective disease control strategies encompass immunization and prophylactic measures to curtail viral spread. The cornerstone of disease management is the swift and precise identification of the etiological agent. Diagnostic protocols must be meticulously optimized for accuracy, ensuring the detection of a broad spectrum of virus variants while discriminating against outgroup viruses (Rubio et al., 2020). The genetic diversity within virus populations significantly impacts both diagnosis and disease management; however, there remains a dearth of information on incorporating genetic diversity into detection methodologies. Diagnostic and disease control techniques for plant viruses are evaluated based on their precision, detection thresholds, multiplexing capacity, quantification, portability, and customizability. High-throughput sequencing offers expansive and precise virus identification, facilitating multiplex detection, quantification, and the discovery of emergent viruses. Viral pathogens constitute a grave challenge to sustainable agriculture, inflicting billions of dollars in losses annually. The emergence of new diseases, driven by factors such as monoculture practices with limited genetic diversity, high-density planting, global trade of plant materials, climate change, and the inherent capacity of viruses to evolve and adapt, is a significant contributor to the rise of these pathogens. Effective disease management hinges on either preventing viral entry into plants or enhancing plant resistance to viral infections through tailored strategies specific to each virus, host, and environmental context [15, 8].

The escalating issue of insecticide resistance poses a significant threat to the efficacy of vector control strategies, particularly in the context of malaria management. The study revealed that the most extensive operational use of insecticides occurs in malaria control, followed by efforts targeting dengue, leishmaniasis, and Chagas disease. However, IRS programs have been sluggish in detecting pyrethroid resistance, and proactive resistance management through the use of alternative, unrelated insecticides remains largely inadequate. The heavy reliance on recently introduced insecticide products raises concerns regarding product stewardship and effective resistance management (Van den Berg et al., 2021). To combat insecticide resistance, vector control programs must enhance coordination in insecticide procurement, strategic planning, implementation, resistance monitoring, and capacity building, while also exploring alternative vector control methods. The World Health Organization initiated the Global Vector Control Response 2017–2030 to strengthen locally adapted and sustainable vector control efforts. Additionally, the Innovative Vector Control Consortium (IVCC) was established to address obstacles in the development of new insecticides for vector control [17].

It delves into the transformative advancements in molecular biology that have significantly impacted plant disease diagnosis and management. It underscores the application of serological techniques, isothermal amplification methods, CRISPR-based innovations, and RNA-based approaches. Additionally, it explores the role of high-throughput sequencing and RNA interference technologies, including host-induced gene silencing and spray-induced gene silencing. Despite existing challenges, these methodologies offer promising avenues for reducing reliance on pesticides while boosting productivity within sustainable agricultural practices. (Devi et al., 2024). The review also examines the concept of quasispecies in plant virology, shedding light on the intricate dynamics within viral populations. In conclusion, it emphasizes the potential of RNA interference and double-stranded RNA technologies for effective plant disease management and pest control Table 1 [4, 10, 6, 7, 19].

Table 1 – Comprehensive Overview of Plant Virus Management

Host and Disease	Crop Affected	Disease Distribution	Causal Agent(s)	Vectors	Disease Effects	Management	References
Tomato Yellow Leaf Curl Virus (TYLCV)	Tomato	Worldwide, especially in tropical and subtropical regions	Tomato yellow leaf curl virus (TYLCV)	*Bemisia tabaci* (whitefly)	Causes severe stunting, upward curling of leaves, interveinal yellowing, and significantly reduces fruit yield.	Management includes the use of resistant tomato cultivars, regular insecticide application targeting whitefly vectors, implementing vector control measures such as sticky traps, and exclusion methods like physical barriers to protect crops from whitefly infestation.	Yan et al. (2021)
Cucumber Mosaic Virus (CMV)	Cucumber, Tomato, Pepper, etc.	Worldwide, with prevalence in temperate regions	Cucumber mosaic virus (CMV)	Aphids (various species including *Myzus persicae* and *Aphis gossypii*)	Symptoms include mottling, chlorosis, leaf curling, stunting, and deformation, leading to reduced fruit quality and yield.	Effective management involves the use of virus-free seeds, cultivation of resistant varieties, control of aphid vectors using insecticides or biological controls, and removal of infected plants to prevent the spread of the virus.	Mohammed et al. (2020)
Potato Virus Y (PVY)	Potato, Tobacco	Global distribution, particularly in temperate regions	Potato virus Y (PVY)	*Myzus persicae* (green peach aphid)	PVY causes mosaic patterns on leaves, leaf drop, tuber necrosis, and significant yield loss in affected crops.	Management practices include the use of certified virus-free seed potatoes, cultivation of resistant potato varieties, control of aphid populations through chemical or biological means, and crop rotation to reduce virus persistence in the field.	Valkonen et al. (2020)
Rice Tungro Disease	Rice	Predominantly found in South and Southeast Asia	Rice tungro bacilliform virus (RTBV), Rice tungro spherical virus (RTSV)	*Nephotettix virescens* (green leafhopper)	Tungro disease causes yellow-orange discoloration of leaves, stunted growth, poor grain filling, and significant yield losses in rice.	Management strategies include the use of resistant rice varieties, control of leafhopper vectors through chemical or biological insecticides, and the adoption of cultural practices such as synchronized planting and field sanitation to reduce vector populations.	Shanmugam et al. (2020)
Barley Yellow Dwarf Virus (BYDV)	Barley, Wheat	Worldwide, particularly in temperate climates	Barley yellow dwarf virus (BYDV)	*Rhopalosiphum padi* (bird cherry-oat aphid), *Sitobion avenae* (grain aphid)	BYDV leads to yellowing of leaves, stunting, delayed maturity, and reduced yield in cereal crops.	Management involves the cultivation of resistant cultivars, control of aphid vectors through the application of insecticides or natural predators, and timely planting to avoid peak vector activity.	Stenger et al. (2017)
Tomato Spotted Wilt Virus (TSWV)	Tomato, Pepper, Peanut, etc.	Worldwide, particularly in warmer climates	Tomato spotted wilt virus (TSWV)	Thrips (various species including *Frankliniella occidentalis*)	TSWV causes necrotic spots on leaves, wilting, reduced fruit yield, and can lead to plant death in severe cases.	Management includes the use of resistant varieties, control of thrips vectors through insecticides, implementation of vector control measures such as blue sticky traps, and weed management to reduce alternative hosts.	Pappu et al. (2019)
Papaya Ringspot Virus (PRSV)	Papaya, Cucurbits (e.g., watermelon, cucumber)	Worldwide, with higher incidence in tropical regions	Papaya ringspot virus (PRSV)	Aphids (various species including *Aphis gossypii*)	PRSV causes mosaic patterns, ringspots on leaves and fruits, reduced fruit quality, and significant yield losses in papaya and cucurbits.	Management strategies include the use of resistant papaya varieties, control of aphid vectors using insecticides, crop sanitation practices, and the roguing (removal) of infected plants to prevent virus spread.	Tripathi et al. (2022)

Grapevine Fanleaf Virus (GFLV)	Grapevine	Worldwide, with higher prevalence in temperate wine-growing regions	Grapevine fanleaf virus (GFLV)	*Xiphinema index* (nematode)	GFLV leads to malformed leaves, reduced fruit yield and quality, and poor vine vigor, significantly impacting grape production.	Management involves the use of virus-free planting material, control of nematode vectors through soil fumigation or nematicides, and the cultivation of resistant rootstocks to minimize virus transmission.	Bertazzon et al. (2017)
Banana Bunchy Top Virus (BBTV)	Banana	Southeast Asia, Pacific Islands, Africa	Banana bunchy top virus (BBTV)	*Pentalonia nigronervosa* (banana aphid)	BBTV causes stunted growth, bunched leaf appearance, and significantly reduced fruit production, leading to economic losses in banana production.	Management strategies include the use of virus-free planting material, vector control through the use of insecticides or natural predators, and the eradication of infected plants to prevent the spread of the virus.	Kiranmai et al. (2018)
Tobacco Mosaic Virus (TMV)	Tobacco, Tomato, Pepper, etc.	Worldwide, particularly in temperate regions	Tobacco mosaic virus (TMV)	Mechanical transmission (via tools, hands, or contaminated soil)	TMV causes mottling, mosaic patterns on leaves, stunting, and reduced fruit yield, with significant economic impact on affected crops.	Management includes the use of resistant varieties, rigorous sanitation measures such as disinfection of tools and hands, crop rotation, and the avoidance of contaminated soil or seeds to minimize the risk of TMV infection.	Reyes et al. (2022)
Citrus Tristeza Virus (CTV)	Citrus (e.g., oranges, lemons, grapefruits)	Worldwide, particularly in citrus-growing regions	Citrus tristeza virus (CTV)	*Toxoptera citricida* (brown citrus aphid)	CTV causes stem pitting, leaf yellowing, reduced fruit size, tree decline, and in severe cases, tree death, leading to major economic losses in citrus production.	Management involves the use of tolerant or resistant rootstocks, control of aphid vectors through insecticides or biological control, and the removal of infected trees to reduce the spread of CTV in citrus orchards.	Dawson et al. (2015)

Materials and Methods

Data on plant virus management were compiled from NCBI, PMD, and contemporary peer-reviewed literature. Integrated methodologies, including the deployment of resistant cultivars and the application of cultural practices, were evaluated for their efficacy in safeguarding and maintaining crop health. The findings were synthesized to underscore the effectiveness of these strategies in mitigating virus prevalence and advancing long-term crop sustainability.

Results and Discussion

Van den Berg et al. (2021) highlight the significant challenges in disease vector control due to reliance on a limited number of insecticide classes and the growing issue of insecticide resistance. Pyrethroids, which are the predominant class of insecticides, have seen reduced use in the African Region owing to extensive resistance. Organochlorines and neonicotinoids rank as the second most utilized insecticide classes. Many nations have been sluggish in addressing pyrethroid resistance in malaria vectors, with numerous countries delaying the transition to non-pyrethroid insecticides for resistance management (IRS). Proactive resistance management for malaria vectors is generally inadequate, with notable exceptions in several African nations. Factors contributing to suboptimal resistance management include the lack of a cohesive national strategy, insufficient monitoring systems, and restricted access to a diverse array of insecticides. The deployment of new insecticide products for IRS must be accompanied by a comprehensive long-term stewardship plan to maintain insecticide susceptibility within vector populations [17, 10]. And Cai et al. (2023) describe Tomato leaf curl New Delhi virus (ToLCNDV) as an emerging pathogen that poses a significant threat to Cucurbitaceae crops, resulting in severe yield losses. Initially identified in China, ToLCNDV is transmitted by whiteflies and can also be mechanically inoculated. The virus causes symptoms such as leaf curling, yellow mosaic patterns, vein swelling, and stunting of the plants. Economic damage from ToLCNDV has been reported in various crops, including cucurbits, with losses reaching up to 20% in central Spain. Nevertheless, genetic resistance to ToLCNDV has been identified in several Cucurbitaceae species [3].

1. Exclusion of Pathogens via Crop Quarantine: Trade routes facilitate the rapid transport of plants and pests, necessitating stringent quarantine regulations to prevent the introduction of pathogens into new regions. These regulations, governed by international agreements and national plant protection organizations (NPPOs), aim to restrict pathogen movement into both novel and limited-distribution areas. For instance, the EU Plant Health Directive is mandated across EU member states, while U.S. federal legislation encompasses nationwide regulations with potential state-specific additions. International phytosanitary efforts are regulated by organizations such as the WTO-SPS Agreement and the IPPC under FAO. Quarantine measures adhere to international standards set by entities like the IPPC and RPPOs, including EPPO in Europe and NAPPO in North America (Barba, Ilardi, & Pasquini, 2015). These recommendations, while not legally binding, guide national governments in formulating risk-based regulations. The EU, for example, enforces pathogen-free standards for imports from non-EU countries, while specific pathogens like PPV are prohibited due to their economic impact [2].

2. Exclusion of Pathogens through Crop Certification: Pathogens primarily spread via infected propagative materials such as rootstocks and buds. To mitigate this risk and ensure high-quality planting material, various certification frameworks have been established. Certification involves collaboration among scientific and technical bodies to guarantee adherence to cultivar type and sanitary status throughout production stages. Key steps include: selecting high-quality plants, maintaining pathogen-free nuclear stocks, and producing certified plants under rigorous conditions. Certification standards are outlined by organizations such as NAPPO and EPPO, addressing steps for pathogen exclusion and detection methods, and ensuring that multiplication history is documented [2].

3. Control of Pathogens by Eradicating Infected Cultivars: Eradication aims to remove pathogens before they become widespread, applicable to plants, fields, or regions. Effective eradication requires timely action, including regular surveys and removal of infected trees. While eradication efforts, such as those targeting PPV, face challenges, timely intervention is crucial for success [2, 9, 14].

4. Controlling Viral Insect Vectors: A few temperate fruit tree viruses are vectored by insects, with PPV being notably transmitted by aphids. Controlling vectors is vital but should be combined with other measures like plant eradication and certification. Insecticide treatments alone are insufficient, as they do not prevent transmission by transient vector species (Barba, Ilardi, & Pasquini, 2015). However, strategies such as preemptive tree removal and the use of mineral oils can reduce virus spread [2, 9, 14].

5. Elimination of Pathogens from Planting Material: Virus elimination techniques include thermotherapy, tissue culture, and cryotherapy. Combining these methods, particularly thermotherapy with shoot-tip grafting or meristem culture, effectively eradicates viruses. Cryogenic techniques, like vitrification and encapsulation–dehydration, have shown high eradication rates and are valuable alternatives when traditional methods fail [2, 9, 14].

6. Selection of Tolerant and/or Resistant Crop Cultivars: Developing virus-resistant cultivars is crucial for managing plant viruses, especially in perennial crops. While breeding for resistance is a long-term endeavor fraught with challenges, some progress has been made. Studies on virus resistance, particularly for PPV, have identified limited sources of natural resistance. For instance, resistant germplasm has been used in breeding programs, and molecular analyses have identified genomic regions associated with resistance [2, 9, 14].

7. Transgenic Approaches to Induce Virus Resistance in Temperate Fruit Trees: Genetic engineering offers a path to introduce resistance traits through specific DNA sequences. However, transformation and regeneration in fruit trees remain challenging, with limited success in commercial genotypes. Early transgenic strategies involved expressing virus-derived sequences, but resistance often depended on RNA-mediated mechanisms rather than viral proteins (Barba, Ilardi, & Pasquini, 2015). For example, the plum cultivar 'HoneySweet' displayed resistance through post-transcriptional gene silencing, showing the complex nature of transgenic resistance strategies [2, 9, 14].

Kumar et al. (2024) discuss the complexities associated with vector management in India, focusing on the containment of vector-borne diseases such as malaria, visceral leishmaniasis, and lymphatic filariasis. Contemporary control strategies including chemical insecticides, bed nets, and environmental modifications are increasingly ineffective due to challenges like insecticide resistance, outdoor biting behavior, and climatic shifts. Innovative vector control measures are emerging, such as insecticide-treated nets, neonicotinoids, clothianidin, and novel formulations. The study underscores the urgent necessity for enhanced resources and support to foster the development and implementation of advanced vector control technologies, offering crucial insights for future research and development endeavors [9]. And in their review, Tatineni and Hein (2023) discuss the profound impact of plant viruses on global agriculture, highlighting the significant losses in crop yield and quality. They elucidate the complexities introduced by emerging viral strains, evolving agricultural practices, co-infections, and climate change, which challenge effective epidemic management. The authors emphasize the use of risk-reducing measures such as exclusion, avoidance, and eradication techniques. They also point out that next-generation sequencing technologies offer promising avenues for detecting novel viruses in quarantine samples. While genetic resistance in crops remains a robust strategy, the long-term efficacy and acceptance of transgenic methods are still under scrutiny. Additionally, they note the potential of CRISPR/Cas9 technology for developing virus-resistant, non-GMO crops [16, 6, 7]. And the same time; Vector-borne diseases (VBDs) such as malaria, dengue, and leishmaniasis inflict considerable morbidity and mortality across the globe, with a disproportionate impact on the most impoverished communities. Vector control has proven to be a more effective strategy than pharmaceuticals or vaccines in mitigating the transmission of these diseases (Wilson et al., 2020). Nevertheless, the emergence of insecticide-resistant vectors and the implications of global environmental shifts underscore the need for sustained investment in evidence-based vector management strategies [20]. And Countries should foster coordination among their vector control programs to enhance efficiency, quality, safety, and sustainability. This can be achieved by sharing information, infrastructure, and human resources. In some instances, a national-level entity manages all vector-borne diseases, whereas, in others, distinct programs address malaria, visceral leishmaniasis, and dengue. Centralization can boost operational efficiency, whereas decentralization can improve safety and sustainability (Van den Berg, Velayudhan, & Yadav, 2021). It is imperative to embrace intersectoral collaboration in vector control, particularly in regions experiencing declining malaria and rising dengue cases. Strengthening entomological capabilities and standardizing application techniques and safety measures for personnel are critical. National guidelines and protocols play a crucial role in maintaining continuity of entomological expertise and resources at both the national and district levels [18].

Types of Plant Pathogens

Plant pathogens are classified into three categories based on their energy acquisition methods: necrotrophs, hemibiotrophs, and biotrophs. These classifications influence plant responses to pathogens.

1 Biotrophic Pathogens: Biotrophic pathogens derive nourishment from living host cells using complex mechanisms. Some, like *Uromyces fabae and Blumeria (Erysiphe) graminis,* are obligate biotrophs that cannot grow on artificial media. Non-obligate biotrophs can grow on artificial media and only damage host cells. Biotrophs form haustoria that penetrate host cell walls but not plasma membranes, with nutrient exchange occurring at the perihaustorial membrane. Pathogens like *Ustilago maydis* and *Cladosporium fulvum* do not form haustoria, and nutrient exchange happens via the apoplast.

2 Necrotrophic Pathogens: Necrotrophic pathogens are opportunistic, unspecialized pathogens that kill hosts quickly and feed on their remains. They do not form haustoria and enter plants through openings or wounds, secreting lytic enzymes and phytotoxins. Examples include *Cochliobolus* (corn leaf blight), *Alternaria* (early blight of potato), and Botrytis (grey mold). Necrotrophic pathogens primarily infect young, weak plants and can be grown on artificial media. Plant immunity against these pathogens involves phytohormones, pathogenesis proteins, and secondary metabolites. Despite some resistance, necrotrophic fungi like *Fusarium* and *Rhizoctonia* can cause significant crop loss.

3 Hemibiotrophic Pathogens: Hemibiotrophic pathogens exhibit characteristics of both biotrophs and necrotrophs, transitioning from a biotrophic phase to a necrotrophic phase. This transition involves suppressing the host's immune response, leading to extensive damage and death. Examples include fungi such as *Magnaporthe grisea, Phytophthora, Pythium, Fusarium, Colletotrichum,* and *Venturia,* and the bacterium *Pseudomonas syringae* [14].

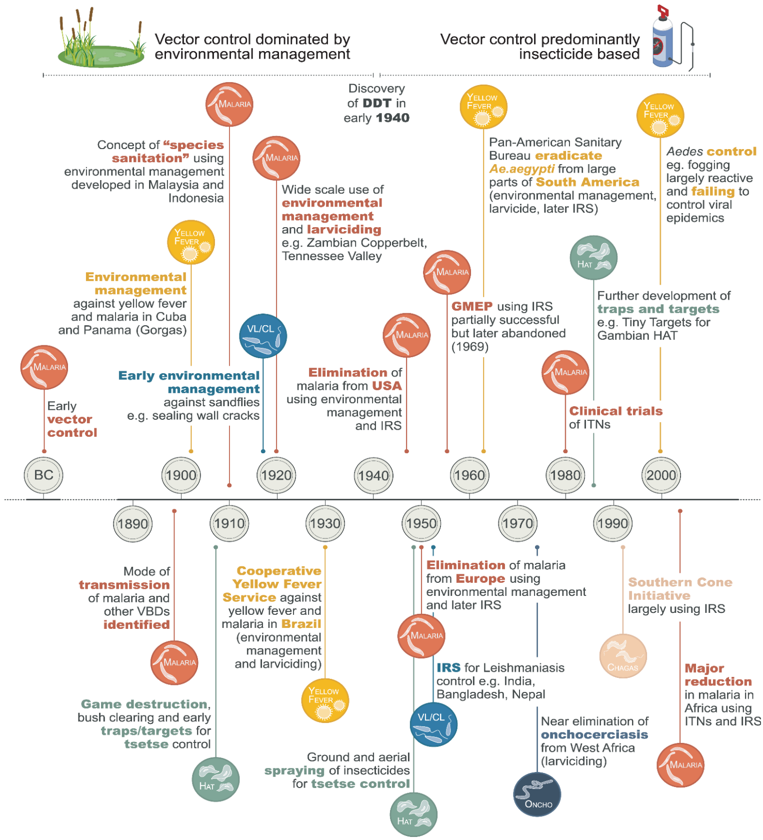

Figure 1 – A brief overview of vector control history includes the following terms: CL (cutaneous leishmaniasis), DDT (dichlorodiphenyltrichloroetha ne), GMEP (Global Malaria Eradication Programme), HAT (human African trypanosomiasis), IRS (indoor residual spraying), ITN (insecticide-treated bed net), VBD (vector-borne disease), and VL (visceral leishmaniasis) [20]. https://doi.org/10.1371/journal.pntd.0007831.g001

Moya-Ruiz et al. (2023) delve into the prevalence and spatial distribution of aphid-borne viruses affecting cucurbits in Spain, underscoring the imperative for robust pest and disease management strategies. Aphids and whiteflies present substantial threats to vegetable crops, inflicting considerable damage and serving as vectors for a variety of plant viral diseases. The inadequacy of current control measures, as highlighted by Moya-Ruiz et al. (2023), underscores the necessity for comprehensive surveillance programs and a deep understanding of virus epidemiology to ensure sustainable food production. The study offers crucial epidemiological insights, including the symptomatic manifestations of virus-infected plants, and highlights the pressing need for further research and the development of innovative approaches to combat aphid pests and their associated viral pathogens. A nuanced understanding of the intricate epidemiology of cucurbit viral diseases will enhance the efficacy of management strategies targeting these pests and the viruses they transmit in agricultural settings [11, 1]. And Machine learning is increasingly employed to elucidate plant virus pathogenesis, particularly in the context of extensive big data. This approach aids in formulating effective management strategies and comprehending host-virus dynamics (Ghosh, Chakraborty, Kodamana, & Chakraborty, 2022). Machine learning techniques are capable of deciphering patterns in virus evolution and devising control measures. Conventional statistical data analysis methods are being supplanted by advanced machine learning and deep learning technologies. Both supervised and unsupervised learning methodologies hold significant promise in biological research, with supervised learning emphasizing labeling and classification [5, 12, 13].

Conclusion

In conclusion, the consideration of plant viruses therefore plays a crucial role in ensuring plant health and safeguarding productivity in agriculture. This review has provided a list of various strategies that when combined presents a holistic and complex approach to managing plant viruses. The effectiveness of these strategies is based on their ability to address different aspects of the viral spread throughout the human body, including preventive measures, diagnostic procedures at the initial stages of the viral infection, and various types of intervention. The evidence supports the belief that an integrated pest management strategy, involving genetic engineering, bio-control, cultural and chemical, offers the best safeguard to protect plants from viruses. The effectiveness of these integrated strategies is well supported by modern literature, which emphasizes the constant need for evolution and new developments due to the emergence of new viruses. It underlines the importance of cooperation between researchers, agronomists, and policymakers in the elaboration of such approaches. Scientific research in the area has improved the understanding of viruses, especially in virology and plant pathology, thus driving progress in virus control measures. While the understanding of the interaction between viruses and their host increases, further work should be devoted to increasing the efficiency of these approaches and discovering fresh approaches to viral control, including gene editing and sustainable agriculture. In other words, crop management cannot be based solely on one or the other but rather a combination of all the presented approaches to ensure sustainable management of crop diseases and pests. By reducing the effects of plant viruses at source and strengthening the systems that support agriculture in a world of evolving environmental conditions, this strategy pays off in the long run. The research supports this hypothesis, affirming that the practice of managing plant virus diseases is exiting and progressive field that holds great potentiality to increase food security in the future.

Highlight

- Integrated Approach: *Effective plant virus management requires the integration of multiple strategies to achieve comprehensive protection and sustainability.*

- Resistant Cultivars: *The use of genetically resistant plant varieties is a fundamental strategy for reducing virus incidence and enhancing crop resilience.*

- Cultural Practices: *Implementing cultural practices, such as crop rotation and sanitation, plays a crucial role in minimizing virus transmission and maintaining soil health.*

- Chemical Controls: *The judicious application of chemical treatments, including antiviral agents and pesticides, complements other management strategies and helps control virus spread.*

- Monitoring and Surveillance: *Regular monitoring and surveillance are essential for early detection and management of virus outbreaks, ensuring timely interventions.*

- Education and Training: *Educating farmers and stakeholders about virus management techniques and best practices enhances the adoption and effectiveness of integrated strategies.*

- ***Sustainability:*** *The integration of these strategies contributes to long-term sustainability by reducing reliance on single-method approaches and promoting overall crop health.*

- Research and Innovation: *Ongoing research and technological advancements are critical for developing new management techniques and improving existing ones.*

- Economic Impact: *Effective virus management strategies help reduce crop losses and improve yield, thus positively impacting the agricultural economy.*

-Global Relevance: *The principles of integrated plant virus management are applicable across different regions and cropping systems, highlighting their universal significance in global agriculture.*

References

1 **Adkins, S., Webster, C. G., Kousik, C. S., Webb, S. E., Roberts, P. D., Stansly, P. A., & Turechek, W. W.** (2011). Ecology and management of whitefly-transmitted viruses of vegetable crops in Florida. Virus Research, 159(2), 110–114. https://doi.org/10.1016/j.virusres.2011.04.016

2 **Barba, M., Ilardi, V., & Pasquini, G.** (2015). Control of pome and stone fruit virus diseases. Advances in Virus Research, 91, 47–83. https://doi.org/10.1016/bs.aivir.2014.11.001

3 **Cai, L., Mei, Y., Ye, R., Deng, Y., Zhang, X., Hu, Z., Zhou, X., Zhang, M., & Yang, J.** (2023). Tomato leaf curl New Delhi virus: an emerging plant begomovirus threatening cucurbit production. aBIOTECH, 4(3), 257-266. https://doi.org/10.1007/s42994-023-00118-4

4 **Devi, B. M., Guruprasath, S., Balu, P., Chattopadhyay, A., Thilagar, S. S., Dhanabalan, K. V., & Jailani, A. A. K.** (2024). Dissecting diagnostic and management strategies for plant viral diseases: What next? Agriculture, 14(2), 284. https://doi.org/10.3390/agriculture14020284

5 **Ghosh, D., Chakraborty, S., Kodamana, H., & Chakraborty, S.** (2022). Application of machine learning in understanding plant virus pathogenesis: trends and perspectives on emergence, diagnosis, host-virus interplay and management. Virology Journal, 19(1), 42. https://doi.org/10.1186/s12985-022-01767-5

6 **Jaybhaye, S. G., Chavhan, R. L., Hinge, V. R., Deshmukh, A. S., & Kadam, U. S.** (2024). CRISPR-Cas assisted diagnostics of plant viruses and challenges. Virology, 597, 110160. https://doi.org/10.1016/j.virol.2024.110160

7 **Kasi Viswanath, K., Hamid, A., Ateka, E., & Pappu, H. R.** (2023). CRISPR/Cas, multiomics, and RNA interference in virus disease management. Phytopathology, 113(9), 1661–1676. https://doi.org/10.1094/PHYTO-01-23-0002-V

8 **Krenz, B., Niehl, A., & Büttner, C.** (2024). Charting the course of plant virology: innovations in diagnostics and beyond – reports from the DPG meeting. Journal of Plant Diseases and Protection, 131(1), 1–7. https://doi.org/10.1007/s41348-023-00818-5

9 **Kumar, G., Baharia, R., Singh, K., Gupta, S. K., Joy, S., Sharma, A., & Rahi, M.** (2024). Addressing challenges in vector control: a review of current strategies and the imperative for novel tools in India's combat against vector-borne diseases. BMJ Public Health, 2(1). https://doi.org/10.1136/bmjph-2023-000342

10 **Mehetre, G. T., Leo, V. V., Singh, G., Sorokan, A., Maksimov, I., Yadav, M. K., Upadhyaya, K., Hashem, A., Alsaleh, A. N., Dawoud, T. M., Almaary, K. S., & Singh, B. P.** (2021). Current developments and challenges

in plant viral diagnostics: A systematic review. Viruses, 13(3), 412. https://doi.org/10.3390/v13030412

11 **Moya-Ruiz, C., Gómez, P., & Juárez, M.** (2023). Occurrence, distribution, and management of aphid-transmitted viruses in cucurbits in Spain. Pathogens (Basel, Switzerland), 12(3), 422. https://doi.org/10.3390/pathogens12030422

12 **Nguyen, C., Sagan, V., Maimaitiyiming, M., Maimaitijiang, M., Bhadra, S., & Kwasniewski, M. T.** (2021). Early detection of plant viral disease using hyperspectral imaging and deep learning. Sensors (Basel, Switzerland), 21(3), 742. https://doi.org/10.3390/s21030742

13 **Niu, Y. D., Hyun, J. E., & Nguyen, N.** (2021). Bacteriophage effectiveness for biocontrol of foodborne pathogens evaluated via high-throughput settings. Journal of Visualized Experiments: JoVE, 174. https://doi.org/10.3791/62812

14 **Pandit, M. A., Kumar, J., Gulati, S., Bhandari, N., Mehta, P., Katyal, R., Rawat, C. D., Mishra, V., & Kaur, J.** (2022). Major biological control strategies for plant pathogens. Pathogens (Basel, Switzerland), 11(2), 273. https://doi.org/10.3390/pathogens11020273

15 **Rubio, L., Galipienso, L., & Ferriol, I.** (2020). Detection of plant viruses and disease management: relevance of genetic diversity and evolution. Frontiers in Plant Science, 11, 1092. https://doi.org/10.3389/fpls.2020.01092

16 **Tatineni, S., & Hein, G. L.** (2023). Plant viruses of agricultural importance: Current and future perspectives of virus disease management strategies. Phytopathology, 113(2), 117–141. https://doi.org/10.1094/PHYTO-05-22-0167-RVW

17 **Van den Berg, H., da Silva Bezerra, H. S., Al-Eryani, S., Chanda, E., Nagpal, B. N., Knox, T. B., & Velayudhan, R.** (2021). Recent trends in global insecticide use for disease vector control and potential implications for resistance management. Scientific Reports, 11(1), 23867. https://doi.org/10.1038/s41598-021-03367-9

18 **Van den Berg, H., Velayudhan, R., & Yadav, R. S.** (2021). Management of insecticides for use in disease vector control: Lessons from six countries in Asia and the Middle East. PLoS Neglected Tropical Diseases, 15(4), e0009358. https://doi.org/10.1371/journal.pntd.0009358

19 **Warghane, A., Saini, R., Shri, M., Andankar, I., Ghosh, D. K., & Chopade, B. A.** (2024). Application of nanoparticles for management of plant viral pathogen: current status and future prospects. Virology, 109998. https://doi.org/10.1016/j.virol.2024.109998

20 **Wilson, A. L., Courtenay, O., Kelly-Hope, L. A., Scott, T. W., Takken, W., Torr, S. J., & Lindsay, S. W.** (2020). The importance of vector

control for the control and elimination of vector-borne diseases. PLoS Neglected Tropical Diseases, 14(1), e0007831. https://doi.org/10.1371/journal.pntd.0007831

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ӨСІМДІК ВИРУСТЫ ТИІМДІ БАСҚАРУ ӨСІМДЕРДІҢ ДЕНСАУЛЫҒЫН ҚОРҒАУ ЖӘНЕ САҚТАУ СТРАТЕГИЯЛАРЫН БІРІКТІРЕДІ

Өсімдік вирусын тиімді басқару өсімдік шаруашылығының тұрақты өнімін және жаһандық азық-түлік қауіпсіздігін қамтамасыз ету үшін маңызды болып табылады. Бұл шолу мақаласы өсімдік вирустарының дақылдарға әсерін жеңілдету үшін біріктірілген стратегияларды зерттейді, вирустарды бақылауға көп қырлы және кешенді тәсілдің қажеттілігін көрсетеді. Бұл зерттеудің негізгі мақсаты биологиялық, химиялық және мәдени тәжірибелерді синергетикалық қолдануды баса көрсете отырып, өсімдік вирустарын басқару бойынша ағымдағы білімді синтездеу болып табылады. Зерттеудің негізгі бағыты сенімді және тұтас басқару жоспарын құру үшін осы стратегиялардың тиімділігін жеке және біріктіріп бағалауды қамтиды. Зерттеу әртүрлі әдістемелерді біріктірудің ғылыми маңыздылығын атап өтеді, олар вирустың таралуын азайтып қана қоймай, сонымен қатар жалпы дақылдардың төзімділігін, өнімділігін және ұзақ мерзімді тұрақтылығын арттырады. Әдістеме әртүрлі дақылдар, аймақтар және қоршаған орта контексттері бойынша әртүрлі вирустарды басқару стратегияларының нәтижелерін бағалай отырып, бар *әдебиеттерді сыни және толық талдауды талап етеді. Негізгі қорытындылар ауыспалы егіспен қатар төзімді сорттарды қолдану және нақты мақсатты пестицидтерді қолдану сияқты кешенді басқару тәсілдері вирустың берілуін, ауырлығын және соған байланысты әсерлерді айтарлықтай төмендететінін көрсетеді. Зерттеу өсімдіктердің вирустарын басқарудың тұтас стратегиясы ұзақ мерзімді өсімдік денсаулығын, тұрақтылығын және өнімділігін қамтамасыз ету үшін қажет деген қорытындыға келеді. Бұл жұмыс тиімді басқару тәжірибесінің кешенді синтезін қамтамасыз ету, болашақ зерттеулер мен практикалық қолдану үшін берік негіз құру арқылы салаға айтарлықтай үлес қосады. Практикалық салдары әртүрлі ауылшаруашылық жүйелерінде осы біріктірілген стратегияларды жүзеге асыру әлеуетінде жатыр, сайып келгенде, өсімдік шаруашылығының тұрақтылығын арттыруға, азық-түлік қауіпсіздігін арттыруға және өсімдік вирустарынан болатын экономикалық шығындарды азайтуға мүмкіндік береді.*

Кілтті сөздер: вирустармен күресу, біріктірілген стратегиялар, дақылдарға төзімділік, тұрақты ауыл шаруашылығы, вирустармен күрес, мониторинг, өсімдіктердің иммунитеті, биоқауіпсіздік.

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ЭФФЕКТИВНОЕ УПРАВЛЕНИЕ ВИРУСАМИ РАСТЕНИЙ ИНТЕГРИРУЕТ СТРАТЕГИИ ЗАЩИТЫ И СОХРАНЕНИЯ ЗДОРОВЬЯ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР

Эффективное управление вирусами растений имеет ключевое значение для обеспечения устойчивого производства сельскохозяйственных культур и глобальной продовольственной безопасности. Эта обзорная статья погружается в интегрированные стратегии смягчения воздействия вирусов растений на урожай, *подчеркивая необходимость многогранного и комплексного подхода к контролю над вирусами. Основная цель данного исследования – синтезировать современные знания о управлении вирусами растений, акцентируя внимание на синергетическом применении биологических, химических и культурных методов. Основное внимание в исследовании уделяется оценке эффективности этих стратегий как по отдельности, так и в комбинации для разработки надежного и целостного плана управления. Исследование подчеркивает научную важность интеграции различных методик, которые не только уменьшают заболеваемость вирусами, но и укрепляют общую устойчивость, урожайность и долгосрочную устойчивость сельскохозяйственных культур. Методология включает в себя критический и исчерпывающий анализ существующей литературы, оценку результатов различных стратегий управления вирусами на разных культурах, в различных регионах и экологических контекстах. Основные результаты показывают, что интегрированные подходы к управлению, такие как использование устойчивых сортов в сочетании с севооборотом и целенаправленным применением пестицидов, значительно уменьшают передачу вирусов, их тяжесть и сопутствующие последствия. В исследовании делается вывод о том, что целостная стратегия управления вирусами растений является незаменимой для обеспечения долгосрочного здоровья, стабильности и продуктивности сельскохозяйственных культур. Эта работа значительно вносит вклад в область, предоставляя всесторонний синтез эффективных методов управления и устанавливая прочную основу для будущих исследований и практического применения. Практические последствия заключаются в потенциале реализации этих интегрированных стратегий в различных аграрных системах, что в конечном итоге будет способствовать более устойчивому производству сельскохозяйственных культур, улучшению продовольственной безопасности и снижению экономических потерь из-за вирусов растений.*

Ключевые слова: борьба с вирусами, комплексные стратегии, устойчивость сельскохозяйственных культур, устойчивое сельское хозяйство, борьба с вирусами, мониторинг, иммунитет растений, биозащита.

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