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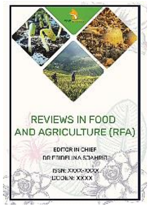

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REVIEW ARTICLE

A REVIEW ON PROPAGATION METHODS OF GRAPE (Vitis Vinifera L).

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ABSTRACT

This comprehensive literature review delves into the intricate world of grapevine (*Vitis vinifera L.*) propagation methods, exploring the historical context, various techniques, and their profound implications for viticulture. Spanning diverse climates globally, grapes are pivotal for wine production, fresh table grapes, and an array of by-products. The propagation methods, including cuttings, grafting, and in vitro techniques, significantly impact genetic diversity, disease resistance, and grape quality. The review underscores the necessity of considering environmental factors, disease resistance, and economic viability when selecting a propagation method, advocating for tailored approaches to local climates and soil conditions. The integration of genetic engineering, ongoing research, and technological advancements emerge as crucial elements shaping the future of grapevine propagation. Quality control in nurseries, economic considerations, and skill development in labour are emphasised for overall success. Real-world examples, such as the success at the Agro-Shtil Nursery in Israel, highlight the effectiveness of grafting, particularly due to its disease resistance, salt-tolerant rootstock selection, time efficiency, and cost-effectiveness. The review concludes with recommendations for collaborative knowledge sharing within the viticulture community, ensuring a holistic and informed approach to grapevine propagation for sustainable and high-quality grape cultivation. This literature review serves as a valuable guide for vineyard managers, researchers, and industry professionals navigating the complexities of grapevine propagation.

KEYWORDS

Grapevine propagation, Vitis vinifera L., Viticulture, Grape cultivation

1. INTRODUCTION

The grapevine *(Vitis vinifera L.*) belongs to the Vitaceae family, comprising approximately 60 wild Vitis species across Asia, North America, and Europe, adapting to various climates. Originating in the Mediterranean, central Europe, and south-western Asia, from Morocco and Portugal to southern Germany and east to northern Iran, grapes serve various purposes, including wine production, fresh table grapes, and dried raisins. Grapes exhibit versatility, being employed in the production of wine, jams, juices, jellies, grape seed extract, ethanol, vinegar, grape seed oil, tartaric acid, fertiliser, and grape-derived antioxidants like polyphenols and resveratrol. Moreover, grapes are associated with potential health benefits, including preventing cancer, heart disease, high blood pressure, allergies, diabetes, and constipation (Abebe, 2017). The propagation of grapes for commercial vineyards involves the use of cuttings, rooting, budding, layers, and grafts (Verdegaal, 2009). Over the past three decades, the global wine industry has undergone a transformative shift from small, traditionally-oriented, family-owned enterprises in Europe to a cosmopolitan industry dominated by multinational corporations, emphasising quality assurance and consistency (Aylward, 2005). Despite this evolution, the grape propagation industry, largely comprising small to medium-sized family businesses and cooperatives, has not witnessed a comparable level of change. While modernization has increased production, the quality of planting material remains inconsistent, particularly in developing countries. The lack of comprehensive standards for grapevine material has led to instances of vine failures and underperforming vineyards needing replanting within 5–10 years of establishment (Smart et al., 2012). Grapevine yield, quality, and vineyard productivity can be significantly enhanced through disease-free planting material and improved management techniques. Certain propagation methods, such as grafting onto disease-resistant rootstocks, contribute to disease resistance, which is essential for sustainable viticulture and mitigating the impact of diseases on grape crops (Alley and Golino, 2000). Grape propagation is a crucial element of viticulture, influencing genetic diversity, disease resistance, and overall grape quality through methods like cuttings, grafting, and in vitro techniques. This literature review delves into the historical context, propagation methods, their pros and cons, environmental considerations, disease resistance implications, recent innovations, and case studies, providing insights for vineyard managers and guiding future research in grapevine propagation. Many instances of failed or underperforming vines were attributed to trunk disease pathogens or other defects affecting establishment, vigour, and longevity (Waite et al., 2013a).

2. OBJECTIVE

In the face of substantial strides in modernization within the grapevine industry the foremost hurdle lies in nurseries' capacity to ensure a steady provision of vines that are robust, in good health, and exhibit uniformity, particularly in developing nations (Borsellino et al., 2012). Achieving this demands comprehensive elucidation of the propagation techniques leading to the generation of top-notch vine seedlings. Additionally, there is a need for systematic comparisons and assessments of various propagation methods, aiding vineyard managers in making well-informed decisions.

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3. Introduction

Archaeological evidence indicates that the domestication of grapevines commenced 6,000–8,000 years ago in the Transcaucasian region, spanning from the Black Sea to Iran, originating from *V. vinifera subsp. sylvestris* populations (Zohary and Hopf, 1993). Our ancestors expanded viticulture and winemaking from primary grape and wine-producing regions, likely aligning with established trade routes for various commodities. Historical maritime routes facilitated the spread of agriculture from the Levant (8500 BC) to Western Europe (5200 BC) during the Neolithic era, covering approximately 1 km per year and disseminating tools and emerging technologies (Mkrtich and Ferreira, 2022).

Although the practice of grafting grapevines dates back to the Christian era, the modern technique has witnessed significant evolution in the past 130 years. This evolution can be divided into three periods: 1) from 1900 to 1950, characterized by a focus on grafting compatibility with different *phylloxera*-resistant rootstocks; 2) from 1950 to 2000, emphasizing the standardization of the production process and phytosanitary certification programs, particularly addressing viruses; and 3) from the 2000s onward, with an increased emphasis on diagnosing and managing new diseases, particularly trunk diseases. This phase also involves adapting production protocols to local nuances and introducing novel certification models (Grohs et al., 2017).

4. Significance of Review

Grapevine propagation holds paramount importance in viticulture as it directly influences grape quality, yield, and disease resistance. The choice of propagation method, such as cuttings or grafting, profoundly shapes the genetic characteristics of grapevines, impacting their adaptability, efficiency, and longevity. Understanding these factors is crucial for vineyard managers seeking to optimise vineyard success and overall grape production (Verdegaal, 2009).

5. Types of Propagation Method

5.1 Sexual Propagation (Seed)

It is well known that seed propagation in any crop presents both advantages and disadvantages. On the positive side, it fosters genetic diversity by combining traits from both parent plants, enhancing the adaptability and resilience of populations. However, the method comes with drawbacks, notably the lack of true-to-type plants. Seeds yield offspring with variable characteristics, leading to plants that may significantly deviate from the desirable traits of the parent cultivar. Additionally, there is an inherent delay in the time to fruit production with seed propagation, posing a challenge for managers seeking more immediate economic returns compared to faster alternatives like vegetative methods. The decision to use seeds for grapevine propagation should consider both the advantages of increased genetic diversity and the disadvantages related to plant variability and delayed fruit production.

5.2 Asexual Propagation (Vegetative)

5.2.1 Cutting

Propagation methods for grapevines encompass softwood cuttings (Warmund et al., 1986). The underlying concept of grapevine propagation through cuttings exploits the plant's capacity to generate roots and shoots from cut stem segments, enabling the replication of desirable grape varieties with consistent traits. Inducing rooting involves the application of synthetic auxins, such as indole butyric acid (IBA), to the bases of cuttings from *V. berlandieri* hybrid rootstocks, which pose challenges in rooting (Nicholas et al., 1992). While IBA application has minimal impact on more easily rooted rootstock varieties *V. vinifera* cuttings root so effortlessly that rooting hormones are seldom necessary (Nicholas et al., 1992). The choice of rooting media stands out as a crucial factor influencing the production of rooted cuttings. It significantly impacts the rooting and growth of grape cuttings (Abebe, 2017). According to optimal rooting often occurs in cuttings derived from the basal portion of the shoots (Hartmann and Kester, 1983). This observation is attributed to the potential higher accumulation of carbohydrates and concentration of endogenous root-promoting substances originating from buds and leaves.

5.2.2 Grafting

This methods for grapevine propagation involves grafting rooted rootstock cuttings directly in the field (Alley, 1957). However, the predominant technique adopted in commercial nurseries centres on bench-grafting dormant one-bud *Vitis vinifera* cuttings onto 300–400 mm dormant hardwood cuttings from carefully selected rootstocks, allowing them to propagate as a single plant (Nicholas et al., 1992). The fundamental concept behind grape propagation through grafting is the ability to unite a desirable grapevine scion with a compatible rootstock, enabling the amalgamation of specific traits for optimal grape production and effective vineyard management (Alley, 1957).

5.2.3 In vitro propagation

Grapevine propagation through in vitro methods is another viable approach. The underlying principle of in vitro propagation for grapes involves the cultivation of plant cells or tissues in a meticulously controlled laboratory setting. This method allows for the regulated regeneration of entire plants outside their natural environment, facilitating the swift and efficient production of genetically identical grapevines. Common in vitro culture techniques, including meristem culture and micro propagation, are routinely employed for the rapid generation of clean, disease-free planting material. The integration of these techniques into producing high-quality planting material holds paramount importance for vegetative propagated crops (Naik and Khurana, 2003).

6. Comparison Of A Sexual Propagation Methods

6.1 Advantages And Disadvantages Of Cutting

Grapevine propagation through cuttings presents a compelling approach with distinct advantages and challenges. One notable advantage is the cost-effectiveness associated with this method, as it eliminates the need for expensive rootstocks and enables the direct cloning of desirable grape varieties. Additionally, the time efficiency of cutting propagation is noteworthy, allowing for faster establishment compared to seed propagation. The success rate is generally high, as cuttings leverage the plant's natural ability to develop roots and shoots, ensuring genetic consistency with the parent plant. However, the impact on grape quality can be variable, with factors such as the health of the parent plant, environmental conditions, and the grape variety influencing the final outcome. Despite these considerations, cutting propagation remains a widely employed and efficient method in viticulture, providing a balance between cost-effectiveness, time efficiency, and genetic consistency in grape production (Singh and Chauhan, 2020).

6.2 Advantages And Disadvantages Of Grafting

Grapevine propagation through grafting is a method that offers both advantages and challenges. On the positive side, grafting allows for the reproduction of specific grape varieties with desirable traits, ensuring the preservation of unique qualities in the resulting vines. This method is particularly valuable for the production of disease-resistant plants, as grafting resistant rootstocks onto them can enhance overall vineyard health. However, the cost associated with grafting materials and the skilled labour required can be higher compared to simpler propagation methods. Time efficiency is a notable advantage, as grafted vines often reach maturity and fruit-bearing stages faster than those propagated from seeds. The success rate of grafting is generally high, especially when conducted by experienced individuals, ensuring genetic consistency. Nevertheless, improper grafting techniques may lead to failure, impacting the overall success rate. The impact on grape quality is positive, with grafting contributing to disease resistance, improved vigour, and enhanced fruit characteristics. In conclusion, grafting is a widely utilised method offering benefits in terms of preserving traits and ensuring disease resistance, but considerations of cost and skilled labour should be balanced against the advantages of enhanced grape quality and quicker fruit production (Alley, 1957).

6.3 Advantages And Disadvantages Of In Vitro Propagation

In vitro propagation of grapevines is a method with distinct advantages and challenges. On the positive side, this technique allows for the mass production of genetically identical plants, ensuring consistency in desired traits and characteristics. It is particularly useful for the rapid multiplication of disease-free grapevines and the preservation of elite genotypes. However, the cost associated with establishing and maintaining sterile laboratory conditions can be relatively high, and specialised equipment and skilled personnel are essential. Time efficiency is notable, as in vitro propagation accelerates the production cycle, enabling faster establishment of vineyards compared to traditional methods. The success rate is generally high, with precise control over environmental factors leading to robust plant development. Despite these advantages, concerns regarding the acclimatisation of in vitro plants to field conditions may arise, impacting their success upon transplantation. The impact on grape quality is positive, as in vitro propagation can contribute to disease resistance and uniformity in fruit characteristics. In conclusion, while in vitro propagation offers benefits in terms of rapid production and genetic consistency, careful consideration of associated costs and challenges, including acclimatization issues, is crucial for successful implementation in commercial viticulture (Barlass et al., 1982).

7. Factors Influencing Choices

When vineyard managers decide on a grapevine propagation method, several critical factors come into play to optimise vineyard success. Climate is a primary consideration, as different propagation methods may be better suited to specific climatic conditions. For instance, in regions with challenging climates or shorter growing seasons, methods that ensure quicker vineyard establishment, such as grafting, may be preferred. Soil type is another crucial factor, with certain grape varieties and rootstocks thriving in particular soil conditions. Vineyard managers must match the chosen propagation method with the soil characteristics to promote optimal root development and overall vine health. Desired grape characteristics, including flavour profile, disease resistance, and yield, significantly influence the choice of propagation method. For instance, grafting onto specific rootstocks is employed to enhance disease resistance and control grape quality. Additionally, considerations of cost and labour, as well as the historical success of a particular method in a given region, further guide vineyard managers in making informed decisions. Ultimately, the complex interplay of climate, soil, and desired grape traits informs the choice of propagation method, ensuring the establishment of healthy and productive vineyards tailored to the unique conditions of each location (Waite et al., 2015).

8. Success Factors and Challenges

8.1 Environmental Factors

The success of grapevine propagation methods is intricately linked to environmental factors, with climate and soil conditions playing pivotal roles. In regions characterised by challenging climates, where frost, extreme temperatures, or shorter growing seasons prevail, vineyard managers often opt for propagation methods that ensure quicker establishment, such as grafting. Grafting onto disease-resistant rootstocks, selected based on soil conditions, is a common strategy to enhance vineyard health and mitigate the impact of soil-borne pathogens. Additionally, soil type profoundly influences the success of propagation methods, as certain grape varieties and rootstocks exhibit preferences for specific soil characteristics. Well-drained soils with optimal nutrient content are essential for root development and overall vine vigour. The choice between propagation methods, whether by cuttings, seeds, or grafting, is guided by a meticulous consideration of these environ ental factors, highlighting the necessity for vineyard managers to tailor their approach to the unique climate and soil conditions of each viticulture region (Reisch et al., 2011).

8.2 Disease Resistance

Each grapevine propagation method contributes uniquely to disease resistance, with implications for the prevalence of common grape diseases. Grafting, a widely used method, involves attaching the scion of a desirable grape variety to a rootstock selected for specific characteristics, including disease resistance. This approach enhances the grapevine's ability to combat soil-borne pathogens such as *Phylloxera* and nematodes, ensuring a more resilient vineyard. Moreover, grafting is instrumental in managing diseases like Pierce's disease, where resistant rootstocks mitigate the impact of the bacterial pathogen *Xylella fastidiosa*. On the other hand, propagation from seeds and cuttings may result in vines being more susceptible to diseases, as these methods do not guarantee the transmission of disease-resistant traits from the parent plant. Seed-propagated grapevines, for instance, may exhibit greater variability in disease susceptibility due to the genetic diversity inherent in sexual reproduction. Understanding how each propagation method influences disease resistance is crucial for vineyard managers in implementing effective strategies for disease prevention and overall vineyard health (Waite et al., 2015).

9. Recent Advances and Innovation

In this recent phase, progress in scientific discoveries has coincided with automation innovations in grapevine propagation. Specialised machinery for grafting, stratification, and plant material collection, along with equipment for phytosanitary treatments, has been introduced. A study by found that a peat and sawdust mixture, in equal parts, proved to be the most effective rooting medium for grape cuttings among various media mixtures (Jaleta and Sulaiman, 2019). Additionally, there is an increased supply of specific chemical and biological inputs for cuttings. Despite these technological strides, challenges have arisen, including the heightened complexity of existing certification programmes and increased production costs. This has led nurseries to make selective choices. Foreseen outcomes in the medium term involve an improvement in vineyard quality, marked by enhanced phytosanitary status, longevity, and production. However, short-term projections indicate limitations in meeting nursery demand, trade restrictions, and a consequent surge in cutting costs (Grohs et al., 2017).

9.1 Technological Advancements

Recent technological tools in grapevine propagation have revolutionised the viticulture industry. Automation has introduced specific machinery tailored for grafting, stratification, and collecting plant material. Advanced equipment for physical phytosanitary treatments ensures improved disease control. Moreover, the availability of specific chemical and biological inputs for cuttings enhances precision and success rates. While these innovations streamline processes and contribute to the overall efficiency of grapevine propagation, it's important to note that the increasing complexity of current certification programmes and production costs poses challenges, impacting nursery selection. Despite short-term limitations, these technological advancements are expected to lead to higher-quality vineyards with improved phytosanitary status, longevity, and production in the medium term (Grohs et al., 2017).

10. Real-World Example

During my 1-year agriculture internship program in Israel, I got the opportunity to work and learn from an Agro-Shtil grape and vegetable nursery in Carmiya, Israel. In this nursery, grapevine propagation exemplifies the successful integration of advanced techniques to elevate grape cultivation. The nursery's commitment to excellence is evident in the meticulous production of plastic trays accommodating 100 pits, which serve as the initial rooting grounds for grape rootstock cuttings. The foundation for robust grape plants is laid through a carefully curated mixture of coconut coir, pit, and moss. The nursery's dedication to quality is emphasized by the selection of genetically improved rootstock, ensuring superior traits such as root quality, disease resistance, and nutrient absorption, and superior traits for scion, such as fruit quality, yield, environment adeptness, and wine quality. The use of controlled environments, drip irrigation, and protective measures, including nylon nets and AI-controlled features inside big greenhouses, further enhances the success of the propagation process.

The multiplication of mother plants is a nuanced process, showcasing the nursery's expertise. The careful selection and preparation of rootstock branches ensure the development of a robust foundation for grapevines. The application of auxin powder and controlled incubation periods contribute to optimal root growth. Transitioning trays to the external environment and gradually exposing them to sunlight exemplifies the nursery's thoughtful acclimatisation strategy.

The grafting procedure, a delicate art, demonstrates precision in joining rootstock and scion. By carefully cutting between nodes of rootstock and ensuring a clean incision, the nursery achieves successful grafting outcomes. The utilisation of temperature-controlled grafting rooms and gradual exposure to external conditions further attest to the nursery's commitment to fostering optimal growth. Removal of rootstock buds and continued nurturing until the joints are strong showcase the nursery's dedication to producing high-quality, ready-for-sale grafted plants. Overall, the Agro-Shtil Nursery's success in grapevine propagation serves as a real-world example of the transform ative potential of advanced techniques in grape cultivation.

11. Conclucion

11.1 Summary

The viticulture industry, centred around the grape (*Vitis vinifera L.*), spans diverse species and climates globally. The major uses of grapes include winemaking, fresh and dried fruit production, and various by-products. Grapevine propagation methods, such as cuttings, rooting, budding, layers, and grafts, play a crucial role in ensuring healthy vineyards. Genetic improvement is essential for sustainable crop productivity, with genetic engineering offering a promising avenue for enhancing resistance to pathogens. Disease-free planting material produced through in vitro culture techniques contributes significantly to grapevine yield and quality. Successful grapevine propagation involves careful consideration of environmental factors, disease resistance, and the economic viability of different methods. Recent advances in automation, machinery, and phytosanitary treatments, coupled with increased complexity in certification programmes, impact nursery selection and are expected to enhance the quality of vineyards in the medium term. Technological tools and advancements continue to shape the industry, emphasising precision and efficiency. In a real-world example, the Agro-Shtil Nursery in Carmiya, Israel, showcases a successful integration of advanced techniques, including controlled environments, precise grafting procedures, and acclimatisation strategies, emphasising the transformative potential of modern methods in grape cultivation. Overall, the dynamic interplay of historical, technological, and scientific factors shapes the evolution of grapevine propagation, influencing the success and sustainability of vineyards globally. Choosing the right propagation method in viticulture is a critical decision, intricately linked to genetic diversity, disease resistance, and grape quality. This choice profoundly shapes a vineyard's adaptability, efficiency, and longevity, underscoring the significance of understanding and selecting suitable propagation methods in the pursuit of sustainable and high-quality grape cultivation.

11.2 Recommendations

Based on the extensive review of grapevine (*Vitis vinifera L.*) propagation methods, encompassing cuttings, grafting, and in vitro propagation, several key recommendations emerge to optimize vineyard success. Firstly, vineyard managers should carefully consider environmental factors, disease resistance, and economic viability when selecting a propagation method. It is crucial to tailor methods to local climates and soil conditions to enhance their effectiveness. Additionally, the integration of genetic engineering, ongoing research and development efforts, and the adoption of technological advancements are vital for the evolution of grapevine propagation. Quality control measures in nurseries, economic considerations, and the continual skill development of labour contribute significantly to the overall success of the propagation process. Notably, grafting stands out as a preferred choice due to its numerous advantages, including disease resistance, salt-tolerant rootstock selection, overall success, time efficiency, and cost-effectiveness. Drawing from real-world examples, such as the success at the Agro-Shtil Nursery, the grafting method proves to be a reliable and efficient choice. In conclusion, fostering collaboration and knowledge sharing within the viticulture community is essential for a holistic and informed approach to grapevine propagation, ensuring the sustainability and success of vineyards globally.

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