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MODERN PROPAGATION TECHNIQUES IN FRUIT CROPS: A REVIEW

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ABSTRACT

In order to guarantee consistency, quality, and quick multiplication of superior planting material, modern fruit production systems depend more and more on effective propagation methods. Fruit crops have long been propagated using traditional techniques such as seed propagation, grafting, budding, cutting, and layering; however, these techniques are frequently constrained by low multiplication rates, seasonal dependence, and the possibility of disease transfer. In addition, most fruit crops cannot retain true-to-type traits through sexual propagation due to genetic heterogeneity due to genetic heterogeneity. Significant developments in plant biotechnology in recent years have resulted in the creation of contemporary propagation procedures that get around the drawbacks of traditional approaches. Fruit crop propagation has been transformed by methods including micropropagation, somatic embryogenesis, synthetic seed technology, cryopreservation, and molecular marker-assisted selection. While somatic embryogenesis promotes regeneration from somatic cells, increasing clonal propagation efficiency, micropropagation allows for the quick, large-scale creation of genetically homogeneous, disease-free plants under controlled conditions. Cryopreservation enables the long-term preservation of priceless germplasm, and synthetic seed technology opens up new options for planting material transit and storage. In addition, during propagation, molecular markers are essential for maintaining genetic integrity and quality control. By facilitating the quick spread of superior cultivars and the preservation of genetic resources, these contemporary methods not only increase propagation efficiency but also promote sustainable horticultural practices. However, obstacles including their high cost, need for technical know-how, and possible somaclonal variation prevent them from being widely used. This paper offers a thorough analysis of contemporary fruit crop propagation methods, emphasizing their fundamentals, uses, benefits, drawbacks, and potential for improving fruit production systems in the future.

***Key words*: Modern propagation, Micropropagation, Fruit crops, Somatic embryogenesis, Cryopreservation, Genetic fidelity, Tissue culture

Introduction

Fruit crops are a vital part of the world's agriculture, making substantial contributions to economic growth, livelihood creation, and nutritional security. They are essential to human diets because they are abundant in vitamins, minerals, antioxidants, and dietary fiber. The demand for high-quality fruit production has significantly increased due to the growing worldwide population and growing awareness of the need to eat healthy food (FAO, 2022). The availability of exceptional planting material that is disease-free, genetically homogeneous, and capable of high yield is required due to this growing demand. Fruit crop production depends heavily on propagation because it directly affects the genetic makeup, growth characteristics, and yield potential of plants. In general, there are two types of plant propagation: sexual and asexual. In fruit crops where uniformity and the retention of elite features are necessary, sexual propagation by seeds leads to genetic recombination and variability, which is frequently undesirable (Hartmann *et al*., 2018). In order to preserve true-to-type traits, the majority of fruit crops are grown asexually or vegetatively. Fruit crops like mango, apple, citrus, guava, and grape have made extensive use of traditional vegetative propagation techniques like grafting, budding, cutting, and layering. Although these methods are successful in preserving genetic homogeneity, they have a number of drawbacks, such as poor rates of multiplication, seasonal restrictions, and vulnerability to disease transmission (Bhojwani & Dantu, 2013). Their efficiency and scalability are further limited by their reliance on trained labor and environmental factors. Plant biotechnology has transformed propagation strategies in recent decades, providing creative ways to get around the drawbacks of conventional approaches. Fruit crops can now be multiplied quickly and widely using modern propagation methods as cryopreservation, somatic embryogenesis, micropropagation (tissue culture), and synthetic seed technologies (Thorpe, 2007). Due to its capacity to generate a high number of genetically homogeneous and disease-free plants in a very short amount of time, micropropagation has become increasingly important among them (George *et al*., 2008). Another cutting-edge method that makes it possible to create embryos from somatic or non-reproductive cells is somatic embryogenesis, which offers chances for clonal propagation and genetic advancement (Fehér, 2015). This technique is especially useful for species for which traditional propagation is challenging or ineffective. Similar to this, planting material may be stored, handled, and transported more easily thanks to synthetic seed technology, which encapsulates somatic embryos or other propagules (Rai *et al*., 2009). Additionally, cryopreservation has drawn interest as a dependable technique for the long-term preservation of plant genetic resources. This method guarantees the preservation of valuable germplasm without genetic modification by keeping plant tissues at extremely low temperatures (often in liquid nitrogen) (Engelmann, 2011). Additionally, by facilitating early selection, genetic fidelity evaluation, and quality control of propagated plants, the incorporation of molecular marker technology has improved propagation efficiency (Collard &Mackill, 2008). Modern propagation methods have several benefits, but their implementation is still restricted in many developing nations because of their high prices, need for specialized infrastructure, and technical know-how. Further difficulties include somaclonal fluctuation and contamination in tissue culture systems (Bairu *et al*., 2011). In order to create sustainable and economical propagation techniques, it is necessary to combine traditional and contemporary methods.With an emphasis on their concepts, methods, applications, benefits, and drawbacks, this review paper seeks to give a thorough overview of contemporary fruit crop propagation systems. Additionally, it emphasizes the field's recent developments and potential for the future, highlighting how they can improve fruit crop production systems' sustainability and productivity.

Principles of Plant Propagation

The efficiency, success rate, and genetic stability of propagated plants in fruit crops are determined by basic biological and physiological factors. These ideas are crucial for creating high-quality planting material and serve as the scientific basis for both traditional and contemporary propagation methods. Researchers and producers can optimize propagation techniques, increase plant survival, and guarantee consistent orchard establishment under various agro-climatic conditions by having a thorough understanding of these topics (Hartmann *et al*., 2018; George *et al*., 2008).

Totipotency

The innate capacity of a single plant cell to regenerate into a whole plant under the right environmental and nutritional circumstances is known as totipotency. The foundation of both contemporary propagation methods and plant tissue culture is this idea. According to George *et al*., (2008), totipotency in fruit crops enables the regeneration of entire plants from explants such as shoot tips, leaves, or meristematic tissues. This idea is widely used in micropropagation for crops including bananas, strawberries, and apples, allowing for the quick growth of genetically homogeneous, disease-free plants (Thorpe, 2007). Additionally, totipotency offers chances for *in vitro* selection and genetic transformation, which improves crop improvement initiatives (Ikeuchi *et al*., 2013).

Cellular Differentiation and Dedifferentiation

The capacity to undergo both dedifferentiation (returning to a meristematic stage) and differentiation (specialization) is unique to plant cells. Differentiated cells can revert to an undifferentiated state during propagation, especially in tissue culture, and then redifferentiate into different plant parts including shoots and roots (Sugiyama, 2015).

For methods like somatic embryogenesis and callus culture, this flexibility is essential. In addition, a crucial component of effective plant propagation systems is the control of gene expression during dedifferentiation, which determines regeneration effectiveness (Fehér, 2015).

Clonal Propagation

The process of creating genetically identical plants from a single parent plant is known as clonal propagation. For fruit crops to retain desired traits including fruit quality, productivity, and resistance to pests and diseases, this principle is crucial (Hartmann *et al*., 2018). To maintain consistency in orchards, vegetative growth techniques like grafting and budding mostly rely on this idea. Additionally, clonal propagation guarantees uniformity in commercial fruit production systems and speeds up the spread of elite cultivars, which is crucial for export-oriented horticulture (Bhojwani & Dantu, 2013).

Genetic Fidelity

In maintaining the genetic composition of the parent plant, genetic fidelity guarantees that propagated plants stay true to type. This is especially crucial for contemporary propagation methods like micropropagation, which grow a huge number of seedlings under carefully monitored circumstances (Bairu *et al*., 2011). However, during *in vitro* culture, variations such assomaclonal variation may occur. In order to ensure the development of consistent and superior planting material, molecular markers are being employed more and more to evaluate genetic stability and identify differences throughout propagation (Collard & Mackill, 2008; Rout *et al*., 2006).

Physiological Maturity

Propagation success is strongly influenced by the physiological age or maturity of plant material. When compared to mature tissues, juvenile tissues typically have a greater capacity for roots and regeneration. Grafting, budding, and cutting fruit crops all depend on choosing the right physiological stage (Leakey, 2004). In addition, the metabolic activity and endogenous hormone levels of plant tissues change with age, which affects how receptive they are to propagation treatments and ultimately determines the plant establishment success rate (Kesari *et al*., 2009).

Role of Plant Growth Regulators (PGRs)

Auxins, cytokinins, and gibberellins are examples of plant growth regulators that are essential for controlling cell division, elongation, and differentiation during propagation. Organogenesis in tissue culture is determined by the ratio of auxins to cytokinins; higher auxin levels encourage the production of roots, while higher cytokinin levels encourage the formation of shoots (Davies, 2010). To optimize regeneration techniques and increase fruit crop propagation efficiency, these hormones must be precisely manipulated (Taiz *et al*., 2015).

Environmental Factors

Propagation success is greatly influenced by environmental factors such as temperature, light, humidity, and nutrition availability. Higher efficiency and survival rates are ensured by current procedures that optimize these aspects through controlled conditions (Kozai *et al*., 2015). In addition, environmental control is essential to successful propagation systems, especially in protected and *in vitro* settings, as variables like photoperiod and light intensity can affect morphogenesis and development patterns (Debergh & Read, 1991).

Conventional Propagation Techniques in Fruit Crops

Fruit crop cultivation has relied on conventional propagation methods for generations. These techniques, which are mostly based on natural plant regeneration processes, are popular because they are easy to apply, reasonably priced, and require little in the way of specialist infrastructure. Conventional fruit crop propagation strategies can be broadly divided into two categories: asexual (vegetative) and sexual (seed-based). Although these techniques are dependable and proven, they frequently have issues with illness control, scalability, and uniformity (Janick, 2005; Westwood, 1993).

Seed Propagation (Sexual Propagation)

Fruit crops such as papaya, citrus (rootstocks), and jack fruit frequently use seed propagation, which is the process of using seeds to grow new plants. This approach is affordable, straightforward, and appropriate for large-scale manufacturing. Additionally, it is essential for breeding operations, since the development of superior cultivars requires genetic variety (Acquaah, 2012). However, because seed propagation causes genetic variability and heterogeneity across plants, it is typically not favored for commercial fruit production. Inconsistency in yield and fruit quality may result from the progeny's failure to maintain the parent plant's desired traits (Singh, 2017). In addition, seed-propagated plants frequently have a longer juvenile stage, which postpones fruiting and financial gains.

Cutting

Using vegetative plant parts like stems, roots, or

Table 1: Comparison of Conventional Propagation Methods.

Method	Crops	Advantages	Limitations
Seed	Papaya, Citrus	Easy, low cost	Genetic variability
Cutting	Grapes, Fig	Simple, fast	Limited species applicability
Grafting	Mango, Apple	True-to-type plants	Skilled labor required
Budding	Citrus, Peach	Efficient, less material	Seasonal dependency
Layering	Litchi, Guava	High success rate	Slow multiplication
Source: (Hartmann & Kester 2002); (Dirr & Heuser 2006); (Mudge *et al*., 2009)			

leaves to create new plants is known as cutting propagation. Fruit crops like grape, fig, pomegranate, and phalsa are frequently grown using this technique. Because of their high success rate and ease of handling, stem cuttings especially hardwood and semi-hardwood cuttings, are frequently used (Hartmann & Kester, 2002). The type of cutting, the environment, and the use of rooting hormones like auxins all affect how well cutting propagation works. IBA, or indole-3-butyric acid, is often utilized to improve root initiation and development. Despite its benefits, this approach may not work for all fruit crops due to species-specific reactions (Dirr & Heuser, 2006).

Grafting

One of the most popular methods of vegetative multiplication for fruit crops like citrus, mango, apple, and pear is grafting. It involves the union of two plant elements that grow together to form a single plant: the rootstock (lower part) and the scion (upper part). This technique combines the best qualities of both parts, such as the rootstock's resistance to disease or stress and the scion's higher fruit quality (Goldschmidt, 2014). Compared to seed propagation, grafting guarantees true-to-type plants and permits early bearing. However, a good union necessitates expert work and appropriate vascular tissue alignment. Its efficacy may also be limited by scion-rootstock incompatibility (Pina & Errea, 2005).

Budding

A single bud serves as the scion in the specialized grafting technique known as budding. This method is frequently used with oranges, peaches, plums, and roses. Because of their effectiveness and high success rates, T-budding and patch budding are popular techniques (Hartmann & Kester, 2002). Budding is beneficial because it permits planting material to multiply quickly and uses less scion material. It is very helpful for large-scale production in nurseries. However, for bark slipping to be successful, budding is extremely reliant on seasonal conditions and requires exact timing (Mudge *et al*., 2009).

Layering

Inducing root growth on a stem while it is still connected to the parent plant is known as layering. The new plant separates and grows on its own after roots are established. Fruit crops including sapota, guava, and litchi are frequently grown using this technique. The most common type of layering in fruit orchards is air layering, also known as marcottage (Hartmann & Kester, 2002). Because the propagule stays linked to the mother plant during root growth, guaranteeing a steady supply of nutrients and water, layering has a high success rate. However, it is not appropriate for large-scale propagation and is a sluggish approach (Bose *et al*., 2001).

Limitations of Conventional Methods

Despite being frequently employed; conventional propagation strategies have a number of intrinsic drawbacks. These include the possibility of disease transmission from parent plants to offspring, poor rates of multiplication, and reliance on seasonal conditions. In addition, many techniques are time-consuming and require expert labor, which limits their scalability in contemporary horticulture (Hartmann & Kester, 2002; Mudge *et al*., 2009). Modern propagation methods that provide more efficiency, quick multiplication, and improved quality control have been developed and adopted as a result of these constraints.

Modern Propagation Techniques in Fruit Crops

Fruit crop production has been transformed by modern propagation techniques, which have overcome the drawbacks of traditional approaches. These methods, which enable quick multiplication, the creation of disease-free plants, and the preservation of priceless germplasm, are mainly based on developments in molecular biology and plant biotechnology. They are especially crucial for large-scale commercial horticulture, where efficiency, consistency, and quality are essential (Altman & Hasegawa, 2012).

Micropropagation: Tissue Culture

Micropropagation is one of the most widely used techniques. In order to create a large number of genetically identical plants, plant tissues are cultured *in vitro* under sterile and regulated environmental conditions. For quick multiplication, this method is often applied to crops like bananas, strawberries, pineapples, and apples (Smith, 2013). Explant selection, culture initiation, shoot multiplication, rooting, and acclimation are some of the steps in the micropropagation process. Light, temperature, nutrition media, and plant growth regulators must all be

Table 2: Stages of Micropropagation.

Stage	Process	Purpose
Stage I	Establishment	Initiation of aseptic culture
Stage II	Multiplication	Rapid shoot proliferation
Stage III	Rooting	Root development
Stage IV	Acclimatization	Hardening and field transfer
Source: (Murashige & Skoog 1962); (Smith 2013); (Merkle *et al.*, 1995)		

precisely controlled at each step. A popular basal nutrient medium for tissue culture is the Murashige and Skoog (MS) medium (Murashige& Skoog, 1962). Among the many benefits of micropropagation are year-round output, a fast rate of multiplication, and planting material free of disease. But it also has drawbacks, including the possibility of somaclonal variation, the high expense, and the need for trained personnel (Larkin & Scowcroft, 1981).

Somatic Embryogenesis

The process of creating embryos from somatic (non-reproductive) cells is known as somatic embryogenesis. Like zygotic embryos, these embryos have the potential to grow into whole plants. Mango, citrus, and oil palm are among the fruit crops that frequently employ this method (Quiroz-Figueroa *et al.*, 2006). Large-scale clonal multiplication and genetic advancement greatly benefit from somatic embryogenesis. Additionally, it is crucial for the creation of synthetic seeds and genetic modification. But the procedure is intricate and necessitates careful adjustment of culture conditions, such as growth regulators and nutritional media (Merkle *et al.*, 1995).

Synthetic Seed Technology

In synthetic seed technology, somatic embryos or other plant propagules are encased in a protective gel-like matrix, typically sodium alginate. Under the right circumstances, these encapsulated structures can be transported, stored, and used for direct sowing (Redenbaugh, 1993). The ease of handling, storing, and exchanging germplasm is one of the technique's many benefits. It is especially helpful for species that are challenging to multiply using traditional techniques. However, for it to be widely used, issues including low conversion rates and poor field performance must be resolved (Rai *et al.*, 2009).

Cryopreservation

The process of cryopreservation involves keeping plant tissues at extremely low temperatures, usually in liquid nitrogen (-196°C), in order to preserve plant genetic resources over an extended period of time. All metabolic activities are essentially stopped at these temperatures, enabling permanent preservation without genetic modification (Reed, 2008). Cryopreservation is used in fruit crops to preserve germplasm, which includes pollen, embryos, and shoot tips. For the conservation of uncommon, endangered, or elite genotypes, this method is very useful. Despite its benefits, cryopreservation's use in environments with limited resources is limited by the need for specific tools and technical know-how (Benson, 2008).

Molecular Marker-Assisted Propagation

Molecular markers are now a crucial tool for modern plant breeding and propagation. According to (Gupta *et al.*, 2010), these DNA-based indicators are used to determine true-to-type plants, evaluate genetic fidelity, and discover changes during propagation. To guarantee the genetic stability of regenerated plants during micropropagation, molecular markers like RAPD, AFLP, and SSR are employed. Additionally, they shorten the time and expense involved in traditional breeding techniques by facilitating the early selection of desirable features. However, sophisticated lab equipment and knowledge are needed for the usage of molecular markers (Semagn *et al.*, 2006).

Advantages of Modern Propagation Techniques

Compared to traditional approaches, modern propagation techniques provide a number of advantages. These include the creation of disease-free plants, the quick multiplication of superior genotypes, and the freedom from seasonal limitations. Additionally, they make it possible to exchange germplasm internationally and conserve genetic resources. In addition, these methods aid in genetic improvement initiatives and sophisticated breeding operations (Altman & Hasegawa, 2012).

Limitations and Challenges

Modern propagation methods have several drawbacks despite their many advantages. Technical complexity, high initial investment, and the need for experienced workers are the main obstacles. Their effectiveness is further restricted by problems including pollution, somaclonal fluctuation, and acclimation losses. In order to increase their use, especially in underdeveloped nations, it is necessary to create affordable and straightforward protocols (Bhojwani & Razdan, 1996).

Applications, Advantages and Limitations of Modern Propagation Techniques

In fruit crop production, modern propagation techniques have several uses and are essential for improving sustainability, productivity, and quality. They are successful not only because they multiply quickly but also because they preserve important genetic resources

Table 3: Comparison of Modern Propagation Techniques.

Technique	Key Feature	Application	Limitation
Micropropagation	*In vitro* cloning	Banana, Strawberry	High cost
Somatic embryogenesis	Embryo from somatic cells	Mango, Citrus	Complex protocol
Synthetic seeds	Encapsulation	Storage/transport	Low conversion rate
Cryopreservation	Ultra-low storage	Germplasm conservation	Technical expertise
Molecular markers	DNA-based analysis	Genetic fidelity	Expensive
Source: (Altman & Hasegawa 2012); (Reed 2008); (Semagn *et al*., 2006)			

and enhance plant health. To fulfill the growing demand for consistent, high-quality planting material across various agroclimatic areas, these technologies are being incorporated more and more into commercial horticulture systems (Cronauer & Krikorian, 1984; Debnath, 2009).

Applications in Fruit Crops

Rapid Clonal Multiplication:

Elite fruit varietals can be multiplied quickly thanks to modern methods like micropropagation. For crops like bananas, strawberries, and pineapples, where industrial cultivation requires huge amounts of consistent planting material, this is especially advantageous (Cronauer & Krikorian, 1984). This promotes the establishment of large-scale orchards, guarantees the timely availability of planting material, and increases producers' overall productivity and profitability under intensive horticultural systems.

Production of Disease-Free Plants:

The creation of pathogen-free plants using meristem and tissue culture methods is one of the most important uses. Fruit harvests are severely hampered by viral infections, which can be eliminated *in vitro* to enhance plant health and yield (Panattoni *et al*., 2013). This promotes environmentally sustainable fruit production systems by increasing productivity, improving fruit quality, and lowering reliance on chemical control methods.

Germplasm Conservation:

Genetic resources are preserved by the widespread use of contemporary propagation methods including cryopreservation and *in vitro* storage. Rare, endangered, and elite genotypes can be preserved for a long time without genetic modification thanks to these techniques (Harding, 2004). Protecting biodiversity, promoting breeding initiatives, and guaranteeing the availability of genetic material for future crop development under changing climate scenarios all depend on such conservation efforts.

Rapid Dissemination of Improved Varieties:

Modern propagation techniques enable the quick multiplication and distribution of enhanced or stress-tolerant cultivars to farmers. This shortens the period between varietal creation and field adoption, which is crucial in situations when the climate is changing (Kumar & Reddy, 2011). Additionally, it makes it possible for research institutes to convey knowledge to farmers more quickly, increasing agricultural resilience and productivity.

Advantages of Modern Propagation Techniques

High Multiplication Rate:

Compared to traditional approaches, modern propagation techniques allow the production of many plants in a comparatively short amount of time. According to Debnath (2009), this is especially helpful in satisfying the growing need for planting material in commercial horticulture. Large-scale orchard expansion and commercial farming are supported by nurseries' capacity to efficiently generate uniform plants due to these techniques' scalability.

Production of Disease-Free Planting Material:

Pathogens are absent from plants grown in sterile, controlled environments. This improves overall crop output and dramatically lowers the frequency of disease in orchards (Cassells, 2012). Healthy planting materials contribute to sustainable and environmentally friendly agricultural operations by ensuring improved plant establishment, lowering crop losses, and reducing the need for chemical treatments.

Genetic Uniformity:

Clonal propagation guarantees that every plant is genetically identical to its parent. In commercial production systems, this consistency is crucial for preserving constant fruit quality, yield, and market criteria (Singh *et al*., 2010). Additionally, it makes crops more marketable, uniform harvesting, and better management techniques possible.

Year-Round Production:

Modern propagation procedures are independent of seasonal variables, in contrast to traditional approaches. Planting material can be produced continuously all year long in controlled conditions (Prakash *et al*., 2004). In the end, this improves production efficiency by guaranteeing farmers a consistent supply of plants and minimizing plantation schedule delays.

Conservation of Genetic Resources:

These methods offer effective instruments for the long-term preservation of plant genetic resources, which is crucial for crop improvement and breeding initiatives (Reed *et al.*, 2011). Additionally, they contribute to the preservation of rare and endangered species that might not be able to live in their natural habitat, preserving biodiversity and ecological balance.

Limitations and Challenges

High Cost of Infrastructure:

Establishing tissue culture labs necessitates a large infrastructure, media, and equipment investment. Small-scale farmers and areas with low resources find it less accessible as a result (Ahloowalia & Prakash, 2004). The extensive use of these technologies in poorer nations is further constrained by high operating expenses.

Requirement of Skilled Personnel:

Professionals with training are needed to handle cultures, maintain sterility, and oversee protocols in modern propagation techniques. Efficiency and success rates might be lowered by a lack of experience. To guarantee that these cutting-edge technologies are properly implemented and adopted, ongoing training and capacity building are crucial.

Risk of Contamination:

One of the biggest problems in tissue culture is microbial contamination. According to Leifert and Cassells (2001), even small contamination might result in culture loss, raising expenses and decreasing productivity. To reduce contamination hazards and guarantee successful propagation, strict aseptic conditions and frequent monitoring are necessary.

Somaclonal Variation:

During *in vitro* propagation, genetic differences may arise, resulting in off-type plants. Genetic faithfulness is impacted, and planting material quality and uniformity may suffer as a result (Jain, 2001). To identify and reduce such variations, regular molecular tool monitoring is required.

Acclimatization Losses:

When transplanted to field circumstances, plants developed under controlled conditions frequently encounter challenges. High mortality rates may arise from improper acclimatization (Pospíšilová *et al.*, 1999). To increase survival rates, proper hardening methods and progressive exposure to outside environments are crucial.

Limited Accessibility in Developing Regions:

Modern propagation techniques are still not widely used in many developing regions due to their high cost and technical limitations. To improve accessibility and encourage broad adoption, low-cost, straightforward, and farmer-friendly technologies are required (Chandra *et al.*, 2010; Sahu, 2013; Rout *et al.*, 2014).

Conclusion

In fruit crop production, modern propagation techniques have become revolutionary instruments, providing notable gains over conventional approaches in terms of plant health, efficiency, and consistency. While traditional propagation methods like seed propagation, grafting, budding, cutting, and layering still have a significant role in horticulture, this review emphasizes how they are frequently limited by factors like low multiplication rates, seasonal dependence, and the risk of disease transmission. On the other hand, many of these issues have been partially addressed- based on plant biotechnology, which have created new opportunities for the quick and extensive proliferation of fruit crops. Due to its capacity to generate large numbers of genetically uniform, disease-free plants under carefully regulated conditions, micropropagation has emerged as the most popular technique among contemporary methods. Similar to this, cryopreservation guarantees the long-term preservation of priceless genetic resources, while somatic embryogenesis and synthetic seed technologies offer creative alternatives for clonal propagation and germplasm exchange. By guaranteeing genetic integrity and assisting with precision breeding initiatives, the incorporation of molecular marker technology further improves propagation efficiency. Modern propagation methods are used for more than only plant multiplication. They are essential to the quick spread of improved cultivars, the conservation of endangered species, and the creation of planting material free of viruses. These methods are especially crucial in light of climate change, as sustainable fruit production systems depend on the creation and dissemination of stress-tolerant cultivars. Modern propagation methods have many benefits, but they also have drawbacks. High expenses, the need for specialized infrastructure, and the necessity for qualified workers continue to be significant obstacles, especially in developing nations. To guarantee the success of these methods, obstacles including somaclonal variation, pollution, and acclimation losses must be well handled. Therefore, efforts should be focused on creating propagation techniques that are affordable, straightforward, and scalable so that farmers and nurseries can readily adopt them. In the future, fruit crop propagation will depend on the incorporation of cutting-edge biotechnological methods including automation, gene editing, and genomics. Propagation systems could be further optimized and made more efficient by new technologies like precision horticulture and artificial intelligence. In addition, the creation of decentralized propagation units and inexpensive tissue culture methods can improve accessibility and encourage broader usage. By increasing the availability and quality of planting material, contemporary propagation techniques have greatly advanced fruit crop productivity. In order to achieve robust and sustainable horticulture systems in the future, their ongoing development and integration with cutting-edge technologies will be essential.

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