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Advancements and practices in budding techniques for kiwifruit propagation

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Abstract. Budding, an efficient method for propagating fruit trees, is a solution to the challenges of sexual reproduction. It has been successfully used on various fruit trees and is a widely practiced technique in many countries. The popular methods of T-budding, chip budding, and patch budding each bring their own unique advantages and limitations. The success of budding is influenced by several key factors, including the right timing, environmental conditions, the selection of scion and rootstock, and the use of wrapping materials. This paper explores the different budding techniques, their benefits, and the factors that determine their success. It also reviews the latest research findings and practical applications in kiwifruit cultivation, highlighting the significant role of budding in increasing productivity and improving the quality of cultivars. This comprehensive analysis is intended to be a valuable resource for researchers, horticulturists, and kiwifruit growers, fostering a deeper understanding of the complexities and innovations in budding techniques.

Keywords: *Kiwifruit propagation, budding techniques, grafting methods, wrapping materials, rootstocks, and scions*

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1. Introduction

Budding is a technique of grafting where a lone bud is utilized as the scion instead of a portion of the stem (Lewis & Alexander, 2008). This method is widely employed for fruit tree propagation in nurseries. It can also be applied to top- work plum, cherry, apricot, peach trees, and young apple and pear trees (Cherry, plum, apricot, and peach trees are not suitable for cleft grafting or whip grafting). Budding and methods are commonly utilized for cultivars that prove challenging to propagate through sexual reproduction or other vegetative means, especially when specific traits of certain rootstocks are desired (Kako et al., 2012). Typically, the buds utilized for the process of budding are commonly located in the leaf axils, positioned between the leaf stalk (petiole) and the shoot, specifically on the side of the petiole that is opposite to the base of the shoot (Lewis & Alexander, 2008).

Propagation of kiwifruit can be accomplished using the asexual technique (Mohammadi & Abdi Senehkouhi, 1993). Asexual techniques encompass budding and grafting, which are performed during the summer and winter seasons, respectively. In order to ensure a successful grafting and budding process, it is imperative to secure the graft union by tying it until the components merge. Tying is pivotal in facilitating healing and safeguarding the buds and scion woods from dehydration. Numerous techniques exist to accomplish this essential task (Hartmann et al., 2007). It is critical to carefully select cultivars such as scion (the upper part of the graft) and rootstock (the lower part of the graft). Typically, kiwifruit vines one to two years old are chosen for scion and rootstock purposes. Selecting rootstock or scion from an older vine may impede the scion-rootstock union, but generally, there are no significant obstacles that can hinder the success of grafting (Cruz-Castillo et al., 1991).

Budding is an essential horticultural practice that facilitates the propagation of particular plant traits by grafting a bud from a selected cultivar onto a suitable rootstock. This technique promotes faster plant maturation, guarantees uniformity, and enables the integration of beneficial attributes such as disease resistance and adaptability. Additionally, budding is an economical approach, aids in the restoration of damaged plants, and allows for the cultivation of various cultivars on a single plant, rendering it a flexible and effective method in horticulture. This review examines the various budding techniques and wrapping materials used. The review also identifies the benefits and rationale of budding in Kiwifruit cultivation.

2. Types of Budding Techniques

2.1. T- budding

T-budding, also known as shield-budding, is a highly efficient technique. Named after the cuts made in the rootstock bark, which are shaped to accommodate the insertion of the scion bud, this method is extensively employed in cultivating citrus and roses. Its rapidity and the significant quantities of budded plants it produces make it the preferred method for grafting and budding, instilling confidence in its use (Lewis & Alexander, 2008).

2.2. Chip-budding

Chip-budding, an alternative to T-budding, is a practical choice in certain situations. It is employed when T-budding is not feasible due to the rootstock bark's inability to lift, potentially caused by unfavorable growing conditions or seasonal dormancy. In cooler climates, chip budding may yield better results than T-budding because callusing occurs more slowly. This technique, with its requirement of only two knife cuts on the rootstock and scion, is efficient and reassuring in its practicality (Lewis & Alexander, 2008).

2.3. Patch budding

This method is employed for species with thick bark or bark prone to splitting along the stem, like walnut and cashew trees, and for species that yield latex, such as sapodilla and jackfruit trees (Lewis & Alexander, 2008). This procedure is quite straightforward, involving the extraction of a section of bark, complete with a bud, from the scion. This section is then utilized to substitute an equivalent-sized piece of bark that has been excised from the stock. The success of this operation is primarily dependent on the ease of detaching the bark from the wood and the robust vegetative growth potential, which are evident in well-pruned scion sources and young, actively growing rootstocks.

2.4. V-budding

V-budding, a novel method, has been employed in cultivating young citrus rootstocks as a viable alternative to micro-budding. It provides the benefits of rapid callus formation due to the active growth of youthful tissues, and the use of young bud wood is easily accessible. The V-budding technique presents the additional advantage of retaining all the leaves on the rootstocks, thereby ensuring uninterrupted growth. However, it is worth noting that manipulating buds and stocks of this magnitude can be challenging, and the storage life of young scion wood is limited, which are essential considerations in its application (Lewis & Alexander, 2008).

2.5. I-budding

I-budding involves creating incisions in the form of the letter 'I' on the rootstock's bark through a single vertical cut and horizontal cross-cuts at each end. Subsequently, a rectangular bud patch resembling that used in patch budding is inserted into the I-shaped incision (Yadav & Singh, 2018). I-budding is similar to patch budding, in which the bud is prepared exactly like in the patch budding technique. The difference lies on the rootstock, where the whole patch of bark is not detached; instead, an I-shaped cut is made in the bark, and a scion is inserted in the cut and tied with parafilm of soft tying plastic.

3. Factors Affecting Success of Budding

3.1. Timing

The success of budding is intricately tied to timing. For instance, in the case of kiwifruit, budding is typically carried out during the late summer or early autumn, when the plant is in its active growth phase and the bark can be easily peeled off. Cherry trees that bud early produce high-quality nursery stock, with August being the optimal time for budding (Vatankhah et al., 2015). Late August to early September is optimal for budding in sweet and sour cherries, whereas mid-August is ideal for plums, apricots, and peaches (Vasilenko, 1991). During February-March and July-August, budding proved highly successful for pome and stone fruits. The process of budding compatibility is greatly affected by the timing of budding as well as the climatic and environmental conditions specific to the region (Baryła & Kapłan, 2012). This understanding of the importance of timing will equip you with the knowledge to make informed decisions in your budding practices.

3.2. Wrapping material

Securing the graft union by tying it until the components merge is crucial to ensuring successful grafting and budding. Tying is vital in facilitating the healing process and preventing the buds and scion woods from drying out. Various methods are available for accomplishing this task (Hartmann et al., 1990). A gentle plastic tape is the most suitable wrapping material for kiwifruit grafting or budding. The nursery adhesive is effective at securely wrapping the budding process. Masking tape is also a satisfactory wrapping material (Beineke, 1978). Rubber strips, electrical tape, or adhesive tape may secure the bud. Tying can be accomplished with sturdy, regular rubber bands. Nevertheless, it is recommended to employ specialized rubber or plastic budding strips (Mayer, 1988). This comprehensive understanding of the role of wrapping materials provides confidence to handle the budding process effectively. Flexible polyethylene tapes can be utilized successfully for kiwifruit budding during spring. Traditional materials such as hemp fiber, plastic string, cotton yarn, or paper tape are not recommended (Zenginbal et al., 2006). White or clear plastic tape is commonly applied to wrap the bud. The wrapping and tying process should be done tightly, ensuring the bud is not covered. In addition to considering the wrap's type and color, the grafting's success can be influenced by various factors. These factors include temperature, hygiene, pests and diseases, humidity, the growth potential of both the scions (buds) and rootstock, the timing of grafting, and the method of grafting and budding. It is also essential to protect the healing union from water loss and drying (Hartmann et al., 2007).

3.3. Budding technique

The budding process through inverted 'T' and 'T' methods on July 1 resulted in the shortest duration for full sprouting, the highest success rate in bud take, and maximum scion length and girth. Therefore, the optimal time and technique for budding the peach CV is on July 1. On 1 July, Shan-e-Punjab on peach, plum, and apricot rootstock is through inverted 'T' or 'T' budding (Shah et al., 2017). In real-world settings, performing chip budding manually yielded superior results for kiwifruit grafting. The manual grafting tool requires additional evaluation using more robust stock and scion plant materials (Celik et al., 2006). The simplicity and speed of techniques such as T-budding and chip-budding make them particularly valuable for amateur horticulturists. With just one well-learned method, a wide range of applications can be accomplished (Awasthi & Negi, 2019). Chip budding at 8–10 cm and 13–15 cm proved highly successful for pome and stone fruits. The wedge and tongue grafting techniques followed closely behind. This detailed understanding of the budding technique will make you feel skilled and competent in your horticultural practices.

3.4. Selection of rootstock and scion

The selection of scion and rootstock plays a crucial role in determining the success of budding. It is essential to choose compatible combinations to ensure efficient nutrient transport and optimal growth. Opting for disease-resistant rootstocks in kiwifruit can significantly improve the overall health and productivity of the plant. The interaction between the scion and rootstock affects various aspects such as water relations, leaf gas exchange, mineral absorption, plant size, flowering, fruit development, fruit quality, and overall yield efficiency (Jayswal & Lal, 2005). The orange tree rootstock, *Citrus aurantium*, produces smooth, thin-skinned, and juicy fruits like sweet orange, tangerine, and grapefruit. Sweet orange rootstocks produce thin-skinned, high-quality fruits, with "Valencia" oranges being more prominent due to dwarfing trifoliate rootstock (Hussein & Slack, 1994). Rootstocks influence bud emergence in 'Hayward' scions, with budburst percentage and duration correlated with flower yield. Treatments with low or high temperatures also show a strong relationship (Wang et al., 1994).

4. Benefits of Budding

Budding is a commonly used method of vegetative propagation that provides many advantages in cultivating fruit trees, especially kiwifruit. Budding has the following primary benefits:

1) The orange tree's rootstock, *Citrus aurantium*, is commonly used and increases its shelf life (Hussein & Slack, 1994).

2) Guava seedlings budded through T-budding have demonstrated superior outcomes in terms of both yield and quality when compared to chip budding (Zamir et al., 2009).

3) Budding is a technique that allows fruit-bearing trees to be cultivated at a much younger stage than plants grown from seeds. This results in an earlier fruit yield, which translates to significant economic benefits. The potential for increased profits is a compelling reason to consider budding in your cultivation practices (Janick & Moore, 1996).

4) Budding ensures that the offspring plants retain the favorable characteristics of the original plant, including fruit quality, size, flavor, and disease resistance. Moreover, budding enables rapid plant multiplication, as a single bud can create a new plant. This leads to accelerated orchard establishment and increased productivity (Hartmann et al., 2007).

5) One key advantage of budding is the ability to use specific rootstocks that complement the scion. This practice enhances plant growth, productivity, and disease resistance, as demonstrated by George and Hall (2008).

6) Budded plants have a shorter period of juvenility than plants grown from seeds, resulting in earlier fruiting and increased overall productivity throughout their lifespan (George & Hall, 2008).

7) Grafting and budding have proven to be successful methods for enhancing the quality of fruits in both ideal growth conditions and saline environments. This adaptability to various settings is a crucial budding feature, as demonstrated by Flores et al. (2010).

8) The budding technique offers a way to finely manipulate the attributes of the emerging plant, including its growth pattern, fruiting period, and overall tree dimensions. These factors can be tailored to meet the specific demands of the environment and the market, thereby saving time and resources and ensuring successful cultivation in diverse conditions (Hartmann et al., 2007).

9) Budding can be performed at different times of the year, offering flexibility in propagation schedules. This allows growers to optimize their propagation activities based on seasonal conditions and labor availability, giving them more control over their cultivation activities.

5. Budding in Kiwifruit

Recent kiwifruit budding advancements have focused on improving success rates and efficiency. Studies have investigated the role of plant growth regulators, such as IBA and Paclobutrazol, in enhancing bud take and subsequent growth. These regulators stimulate root formation and control shoot growth, thereby improving the success rates and efficiency of kiwifruit budding. Additionally, research on the genetic compatibility between kiwifruit cultivars and rootstocks has provided insights into optimizing budding practices.

Combining IBA at 3500 ppm and Paclobutrazol at 500 ppm has shown promise in improving the rooting response and other aspects of kiwifruit semi-hardwood cuttings (Ali et al., 2017), providing useful ways to make kiwifruit farming better. The combination of rootstock and scion can regulate hormone production and its impact on different parts of grafted and budded plants (Yamasaki et al., 1994). Regarding the basal diameter of shoots near the grafted point, only the hybrid rootstock A. deliciosa × A. arguta showed poor results (Kwack et al., 2011). Different rootstocks influenced the emergence of buds in 'Hayward' scions, and there was a strong connection between the blooming process and budburst. The number of flowers per shoot showed a significant correlation with the budburst's percentage and duration (Wang et al., 1994).

6. Varieties and Cultivars of Kiwifruit

Kiwifruit stands out as a crop due to its unique commercial production and international trade, which are centered on the distinctive Hayward cultivar. The Hayward plants, first introduced in the late 1930s, quickly gained popularity, leading to the establishment of commercial orchards in New Zealand. Despite the initial dominance of other cultivars like Abbott, Allison, and Bruno, Hayward's larger size, attractive appearance, and delightful flavors eventually set it apart (Ferguson, 1991).

Kiwifruit, known for its unique taste and vibrant green color, is not only a delicious fruit but also a nutritional powerhouse. It is rich in vitamin C, vitamin K, vitamin E, folate, and potassium, making it a healthy addition to any diet. Additionally, it is a valuable source of dietary fiber, which is beneficial for digestive health. Two main categories of Kiwifruit are grown worldwide: *Actinidia deliciosa* and *Actinidia chinensis*. *Actinidia deliciosa* includes different varieties like Hayward long, Hayward round, Abbot, Allison, Bruno, and Monty, while *Actinidia chinensis* consists of Red Kiwi, Hort 16, and Golden Kiwi (Sims, 2011; Dhakal, 2018).

7. Practical Applications and Reasons of Budding in Kiwifruit Cultivation

Budding is widely employed in the commercial cultivation of Kiwifruit to propagate new cultivars and replace older, less productive plants. It offers a cost-effective and efficient approach to ensuring uniformity and improving fruit production quality.

Moreover, budding enables the swift integration of new varieties with improved traits, such as disease resistance to common kiwifruit diseases like *Pseudomonas syringae* and enhanced fruit quality in terms of size, taste, and shelf life.

The commercial potential of kiwifruit production in Nepal is apparent due to the presence of potential markets within the country itself, as well as in India and Bangladesh. Additionally, scientific literature from various countries offers valuable insights into the kiwi fruit's climatic requirements, further bolstering its cultivation's feasibility in Nepal's warm temperate climate (Basnet et al., 2016). Despite the considerable potential for producing high-quality kiwifruit in Nepal, the industry needs more knowledge regarding certain aspects of kiwifruit production. This lack of awareness has resulted in adverse effects on the industry. It is crucial that we, as a community, recognize the importance of knowledge and awareness in improving kiwifruit production. However, Nepal possesses numerous prospects to improve the commercial production of Kiwifruit, catering to both domestic consumption and international exports (Khanal et al., 2022).

It is important to understand that grafting and budding play a pivotal role in the commercial propagation of a wide variety of fruit trees, such as apples, citrus, grapes, mangoes, apricots, peaches, pears, persimmons, plums, sweet cherries, and walnuts. This technique, particularly beneficial for species with highly heterozygous varieties that do not readily root from cuttings (Nawaz et al., 2016), can be utilized in Kiwifruit for better orchard establishment, summer propagation, disease resistance, desired cultivar and traits, and higher quality produce.

8. Conclusions

Budding, a vital vegetative propagation technique in kiwifruit cultivation, is a cost-effective method that promotes high-quality, disease-resistant, and environmentally adaptable cultivars. It accelerates the fruit-bearing process, providing a faster return on investment. Budding's versatility allows for simple conversion of existing orchards to new cultivars, improving rootstock performance and survival rates. It is suitable for small-scale and large-scale operations, preserving rare and heirloom varieties while maintaining genetic diversity. Advancements in plant growth regulators and genetic compatibility studies have improved budding success rates and efficiency. As the industry moves towards sustainable practices, budding's importance will grow, with it at the forefront of agricultural advancements.

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