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Original Research Paper

Unlocking the potential of kiwifruit (*Actinidia* spp.) pot cultivation: A Novel approach for fruit-bearing potted plant production by air layering

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ABSTRACT

Kiwifruit potting is used extensively in ornamental plantations. However, the procedure of pot cultivation with fruit-bearing via air layering is still not yet developed. In this study, several treatments were used to induce rooting via air layering, including wounding, hormone use, and environmental conditions. The results showed that both wounding operations such as scraping and girdling, were effectively inducible for rooting in kiwifruit. Application of continued 100 mL ½ Murashige & Skoog (MS) + 0.5 mg/L Indole-3-butyric acid solution every 7 days can significantly enhance the rooting rate by up to 83.33% as compared to plant growth-promoting rhizobacteria, which inhibited rooting. Finally, the rooting canes with fruiting were cut and transferred into the pot, the fruit grew well. Taken together, the developed method provides insight into an efficient way to produce kiwifruit potted plants with fruits in four months that are directly available for commercial sale and scientific research.

Keywords: Potting technique, propagation, rooting efficiency, wounding operations

INTRODUCTION

Kiwifruit is popular among consumers for its richness in nutrients such as vitamin C and dietary fiber (Mi et al., 2023; Wu et al., 2025). Kiwifruit is a large and perennial woody plant known for its twisting and winding growth, dense foliage, and fragrant flowers, making it suitable for vertical greening on trellises and walls, as well as for use as a decorative house plant, offering significant ornamental value (Rana & Kumar, 2021). Furthermore, kiwifruit grows on one-year-old fruiting canes (Rymbai et al., 2022). By inducing root formation and cultivating these branches as potted plants, it is possible to achieve on-tree preservation, providing fruits at their optimal flavor. Therefore, potted kiwi plants that bear fruit in the same year offer multiple uses, including ornamental, edible, and on-tree preservation, holding substantial social and economic value (Hazarika et al., 2022).

The main methods of kiwi propagation include seedling propagation, grafting, division, cutting, and air layering. Firstly, seedling propagation has a relatively long juvenile period, typically requiring 3-5 years for the tree to bear fruit (Hazarika et al., 2022). Due to the dioecious nature of kiwi plants, offspring traits segregate, resulting in significant differences in fruit quality compared to the parent plants, which delays and destabilizes commercial planting benefits. Additionally, since male plants only flower and do not bear fruit, accounting for about 50% of the population, orchard yield and economic efficiency are further reduced (Abbate et al., 2021). Secondly, grafting fruiting branches is another method to achieve fruiting within the same year, but this method has significant uncertainties. It is influenced by graft compatibility, branch fullness, nutritional status, and changes in the external growth environment, which can lead to issues such as flower drop, fruit drop, and small fruits (Li et al., 2021). Thirdly, cutting and air layering propagation can produce large seedlings, shortening the time from planting to benefit. However, air layering produces fewer roots and lateral roots, resulting in a low survival rate after transplanting, limiting its application in production. Therefore, there is a need to optimize rooting parameters and improve techniques.

Fruit-bearing pot cultivation is still a challenge so far, hence obtaining fast-fruiting plants is an interesting, commercially valuable, but challenging endeavor. Kiwifruit potting culture has been largely used in ornamental horticulture for vertical gardening as well

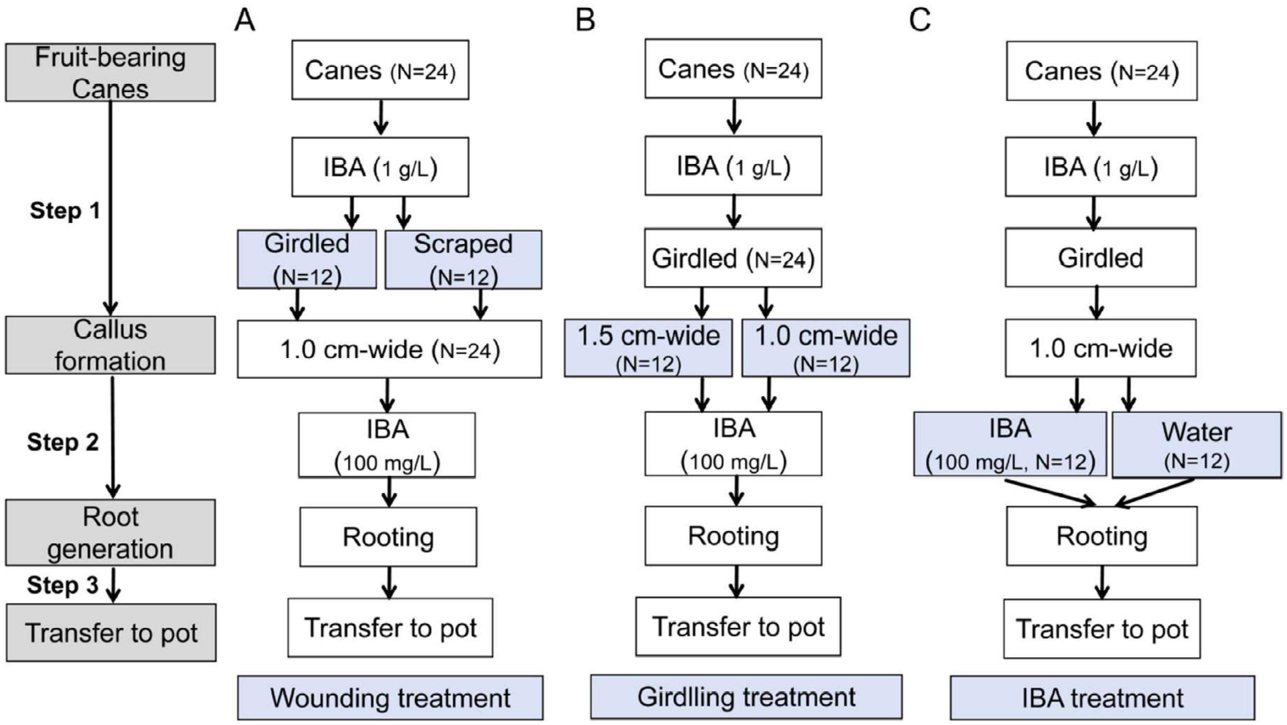

Fig. 1 : Experiment design for callus formation and rooting for fruit-bearing canes

A. wounding treatment for callus formation, B. effects of different girdling widths on callus formation, C. IBA treatment for rooting rate

as for edible fruit production but there is no report of fruit-bearing kiwifruit in pot via air layering. Although Black et al. (2012) and Mullins & Rajasekaran (1981) have documented the fruit-bearing pot cultivation in *Actinidia arguta* and grapevine cuttings, respectively, it is essential to emphasize that their respective investigations did not incorporate air layering. Propagation through air layering can achieve the production of kiwifruit within a short period yet poor root growth may limit the survival rate of transplanted canes with fruiting; therefore, optimized rooting parameters and technical improvements are needed.

Several factors affect the rooting rate for air layering. Investigations have been undertaken to elucidate the significant effects of varying methods of wounding and branch diameters on the enhancement of branch rooting (Xie et al., 2023). Furthermore, Erturk et al. (2010) concluded that the PGPR (plant growth-promoting rhizobacteria) was involved in stimulating root development in semi-hardwood and hardwood kiwifruit stem cuttings along with root functioning and plant nutrition. IBA (Indole-3-butyric acid) concentrations have also been demonstrated as an activator for callus formation to promote rooting (Mao et al., 2018). However, understanding this treatment for fruit-bearing potted plants is still unclear.

In this study, the kiwifruit canes with fruit were subjected to air layering and different treatments were applied to observe the root growth. We proved that different wounding operations (girdling and scrapping), and various cane diameters along the IBA application can successfully induce the rooting efficiency in kiwifruit canes via air layering, whereas, PGPR has been observed to inhibit the rooting process. Consequently, we have developed specific strategies that can be used to improve potting culture in kiwifruit by promoting root development through air layering.

MATERIALS AND METHODS

Plant materials and testing reagents

The present study involved the use of the 'Cuiyu' kiwifruit (*A. chinensis* cv. Cuiyu), an extensively grown cultivar in China due to its delicious flavor and resistance to diseases (Zhong et al., 2002), which was sourced from the kiwifruit orchard located at Huazhong Agricultural University in Wuhan, China (114° 37' E, 30° 48' N). The sampling strategy encompassed the careful choice of disease-free one-year-old biennial fruiting canes for evaluating the rooting rate. A stock solution of 1.0 g/L of IBA (3-Indole butyric acid) was prepared using the following procedure: 1 g of IBA (Coolaber Science & Technology Co., LTD) was added to a 100 mL flask, and then 2 mL of alcohol was added to dissolve the powder. Volume was brought to 1 L with distilled water, obtaining 1000 ppm IBA stock solution. The specific rooting experiment was conducted using a liquid medium denoted as ½ MS (Murashige & Skoog) + 0.5 mg/L IBA (Martini & Papafotiou, 2007).

Wounding treatment

A knife was sterilized with a 75% alcohol solution before every girdling for 30 seconds and then allowed to dry naturally. Upper and basal ends of targeted canes were identified and wounding operation was carried out at a distance of 3-5 cm above the fourth leaf from the basal end. Two distinct groups of canes were treated as described in Fig. 1A. The first group: a 1.0 cm wide phloem was girdled at 360° and the second group: a 1.0 cm wide phloem was scraped at 360°.

Width of girdling treatment

To investigate the effects of different widths of girdling on callus formation, two distinct groups of canes were treated (Fig. 1B). The first group: a 1.0 cm wide phloem was girdled at 360° and the second group: a 1.5 cm wide phloem was girdled at 360°.

IBA treatment

To investigate the effects of IBA on rooting formation, two groups of canes were used (Fig. 1C). For the first group, the 1.0 g/L IBA stock solution was administered to the wound site for a duration of 30 seconds. Subsequently, 100 mL dilution of IBA (i.e. 100 mg/L) was administered at intervals of 7 days, persisting for the duration of one month. Next, 100 mL ½ MS + 0.5 mg/L IBA solution was sprayed every 7 days. For the second group, 1.0 g/L IBA was also applied to the wound site and then watered with 100 mL ½ MS every 7 days.

PGPR application for rooting test

To test if PGPR can enhance inducing rooting rate, the composite mixture was divided into two distinct treatment groups. Within the context of the initial treatment, an incorporation of 10 g of PGPR was executed into the composite mixture. Whereas, in the context of the second treatment, the application of PGPR was omitted, and distilled water was set as controlled.

Preparation of composite matrix

A composite matrix comprising peat, perlite, and vermiculite was formulated at a proportion of 2:1:1. Subsequently, sterilization was carried out utilizing high-pressure steam. Following sterilization, 1 g of carbendazim powder per kilogram of the composite mixture was added. This addition was accompanied by thorough stirring consequent to the addition of 100 mL of distilled water to achieve appropriate moisture levels. The above-mentioned wounded canes were enveloped with the prepared composite mixture, creating dimensions of approximately 8-10 cm in length and 6-8 cm in diameter on the outer surface of the canes. These wrapped wounds were then tightly encased using a black plastic sheet. To facilitate proper aeration and drainage, a modification was made to the black plastic sheet by creating a funnel-like shape through a cut made 4-5 cm from the top. Additionally, six holes, each with a diameter of 1 cm, were carefully drilled into the plastic sheet. The manipulation of the plastic sheet aimed to sustain adequate humidity levels of 70-80% and oxygen concentrations of 10.35-20.03% within the composite mixture.

Transplantation to pot

The canes with rooting were cut off 3 cm below the wounding site and transplanted into the 30×30 cm pots. Afterwards, these pots were relocated to a greenhouse environment to facilitate the observation of fruit development, maintaining a relative humidity of 75% at 20°C. The fruit size was determined when the fruit was on the vine, and the fruit size was measured when the fruit reached the harvest window of 6.5%~8.0% soluble solid content.

Statistical analysis

All experiments were arranged as a completely randomized design, with individual canes serving as the experimental units and treatments randomly assigned. Statistically significant differences between cane diameter and callus diameter were determined by SPSS 26 (One-way ANOVA) and Excel software (Student's t-tests, version 2017).

RESULTS AND DISCUSSION

Callus formation in responses to varied wounding approaches and cane diameter

To understand if wounding methods affect the formation of callus, scraping and girdling were respectively applied on one-year-old canes of 'Cuiyu' kiwifruit. The results showed that both methods can induce callus formation, but the girdling method produced 3.3-fold thicker than that of the girdling treatment (Fig. 2A, B). In addition, to test if the width of the girdling affects callus formation, we compared girdling of 1.0 cm-wide and 1.5 cm-wide canes. As a result, girdling of 1.0 cm-wide can induce 2.37±0.30 cm of callus in diameter, which is significantly wider than those in 1.5 cm-wide (1.82±0.45 cm) at ~60 days after inducing IBA ($p=0.01$, <0.05) (Table 1).

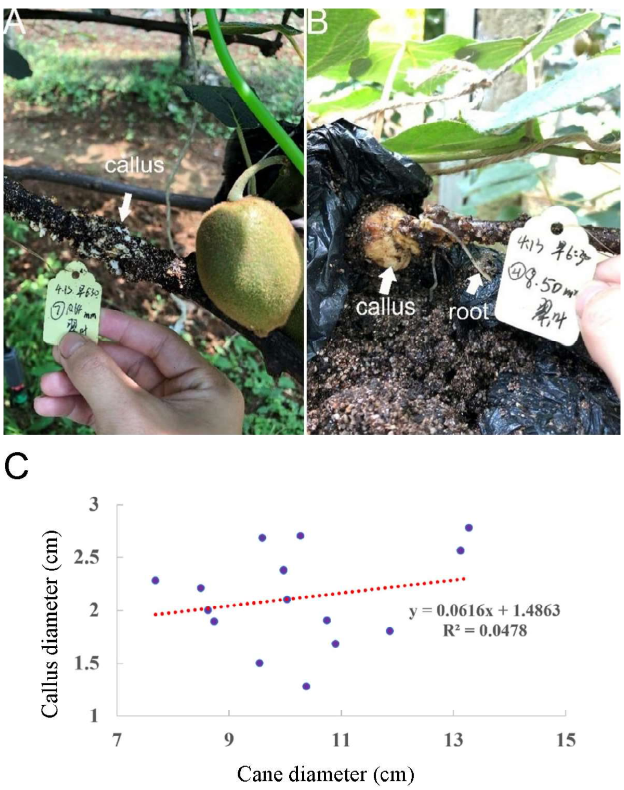

Fig. 2 : Callus formation in response to varied wounding approaches and cane diameter

A. callus formation in response to scraping at 56 days after treatment, B. callus formation in response to girdling at 56 days after treatment, C. relationship between cane diameter and callus diameter

Table 1 : The width of the girdling affects callus formation

Fruit number	Girdling width (1.5 cm)	Girdling width (1.0 cm)
1	1.68	2.00
2	1.90	2.68
3	2.70	2.10
4	1.28	2.28
5	1.89	2.56
6	1.80	2.78
7	1.50	2.21
8	-	2.38
Average	1.82	2.37
std	0.45	0.28
Student's t-tests	0.01	

Among the girdling canes, we then investigated the effect of cane diameter on callus generation. A diameter ranging from 7.69 to 13.28 mm (the average=10.22±1.61, N=16) was used for testing the ability of callus generation. The results showed the callus can be induced for all these diameter ranges, and the relationship between cane diameter and callus diameter is only $R^2=0.048$ (Fig. 2C, Table 2), indicating the cane diameter was observed to have no significant effects on the rooting rate. Therefore, 1.0 cm-wide girdling operation was used to improve the callus before rooting.

Table 2 : The relationship between cane diameter and callus diameter

No.	Cane diameter (cm)	Callus diameter (cm)
1	7.69	2.28
2	8.501	2.21
3	8.63	2
4	9.6	2.68
5	9.98	2.38
6	10.04	2.1
7	13.13	2.56
8	13.28	2.78
9	8.74	1.89
10	9.55	1.5
11	10.28	2.7
12	10.38	1.28
13	10.75	1.9
14	10.9	1.68
15	11.87	1.8

Consequences of continuing application of IBA on root development

IBA has been documented to be an activator for rooting (Cristofori et al., 2010). Therefore, investigated the effect of the IBA application on the rooting rate in kiwifruit. The commercial recommended concentration of IBA (100 mg/L) was used to treat girdling plants, and distilled water was set as a control. The results showed that the average rooting rate in plants with IBA application was 83.33%, while the group without application of IBA did not develop any roots. Hence, plant growth regulator treatment significantly promoted the rooting in kiwifruit.

Impacts of PGPR on root enhancement

PGPR was reported to affect plant rooting. To investigate if the PGPR treatment also affected the rooting rate in kiwifruit, the normal concentration of PGPR (10 g/L) was applied after girdling the canes, and distilled water was set as a control. The results showed that the average rooting rate of the 10 g/L PGPR treatment group was only 8.33%, while the average rooting rate of the non-PGPR treatment group reached 50.00% (P=0.024). Therefore, the PGPR application can significantly reduce the rooting rate of kiwifruit during the air layering process.

Fruit size determination

To investigate if the approach of fruit-bearing potted cultivation impacted fruit size, fruits, were harvested from the canes grown via fruit-bearing potted cultivation and from normally grown vines at the harvesting window, and then comparatively analyzed their fruit size. The results showed that continued IBA stimulation and nutrient supply were found to promote root formation without affecting fruit size (Table 3 & 4).

The present study sought to examine the impacts of various factors, including cane diameter variations,

Table 3 : The comparison of the fruit after approach of fruit-bearing potted and normal grown of fruit on vine

Fruit size	Diameter of the fruit between stylar end and stem end		Diameter of the equatorial part of the fruit	
	Girdled fruit (N=10)	Control (N=10)	Girdled fruit (N=10)	Control (N=10)
Average	4.40 cm	4.32 cm	3.33 cm	3.21 cm
std	0.90 cm	0.91 cm	0.74 cm	0.76 cm

Table 4 : The relationship between cane diameter and callus diameter

Fruit number	Diameter of the fruit between stylar end and stem end		Diameter of the equatorial part of the fruit	
	Girdled fruit	Control	Girdled fruit	Control
1	4.65	5.97	3.67	4.17
2	6.20	3.34	4.58	2.50
3	5.00	4.19	4.17	3.00
4	3.44	3.72	2.70	2.56
5	4.21	3.90	2.97	2.86
6	4.90	3.98	3.40	2.65
7	4.36	4.56	3.82	3.80
8	4.52	5.90	3.22	4.73
9	3.60	4.00	2.40	3.06
10	3.10	3.65	2.38	2.79
Average	4.40	4.32	3.33	3.21
std	0.90	0.91	0.74	0.76

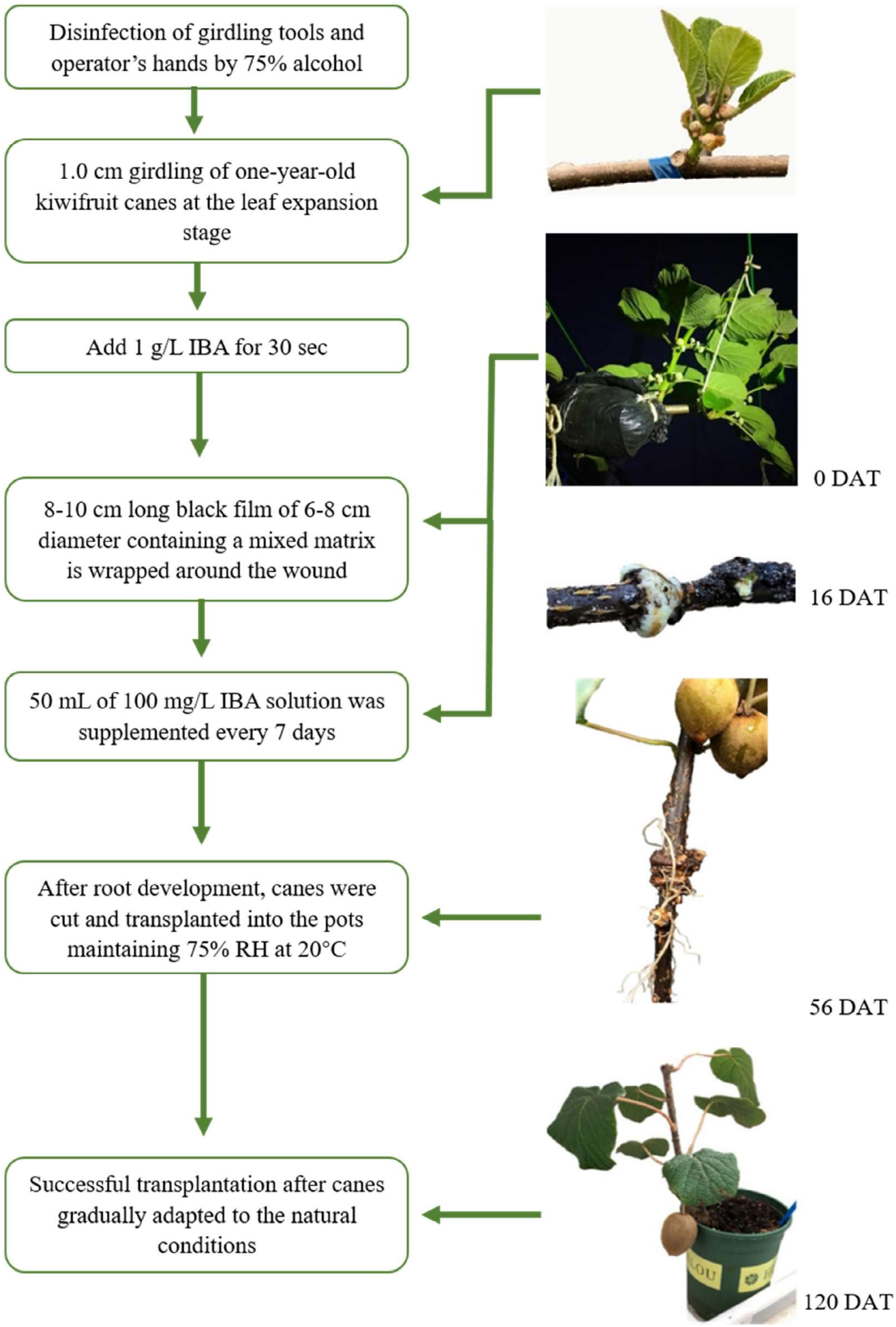

Fig. 3 : Technical method of air layering to get fruit-bearing potted kiwifruit

wounding techniques on the callus formation efficacy, as well as IBA and plant growth-promoting rhizobacteria (PGPR) on the rooting efficacy of the fruit-bearing canes through the process of air layering in kiwifruit. This aspect underscores the distinct sensitivity responses of cellular tissues to the influences of plant growth regulators and multiple wounding methodologies. Additionally, fruit-bearing canes were subjected to air layering, it is still unclear if the presence of the fruit has any effect on rooting and requires further investigation.

In this aspect, PGPR is claimed to be effective in enhancing root development (İşçi et al., 2019). However, the results in this experiment are contrary to the above conclusions, as the rooting rate of PGPR-treated plants was significantly lower as compared to the non-PGPR-treated group. Erturk et al. (2010) and İşçi et al. (2019) found that the PGPR was involved in stimulating root development in kiwifruit and grape stem cuttings along with root functioning and plant nutrition. However, in the present study, the PGPR was mixed with a matrix wrapped around the wound and was largely affected by the growing conditions, such as high temperature and rainy weather in the field. We therefore speculate, that this inhibitory effect may be due to the indirect alteration of the soil environment by fluctuation in the microbial community, such as hormones, oxygen, humidity, etc., which subsequently affected root development. It was supported by the findings that PGPR can alter hormone homeostasis or rhizosphere environment (Mellidou & Karamanoli, 2022). The specific influencing factors require further investigation.

Among the various wounding methods examined, the girdling approach demonstrated a notable 3.3-fold increase in thickness compared to the girdling treatment (Fig. 1A, B). Specifically, the findings indicate that employing a 1.0 cm-wide girdling technique resulted in the formation of a broader than the callus produced using a 1.5 cm-wide method. Consequently, a prudent approach involves the selection of canes with intermediate diameters to optimize the rooting process in kiwifruit propagation.

As far as IBA is concerned, used alone or in combination with other growth hormones significantly produced the highest rooting (Lakho et al., 2023). Similarly, at a concentration of 1500 or 2000 mg kg^{-1}, IBA gave comparable effects for improving root performance (El-Banna et al., 2023). This study confirmed that continuous hormone stimulation and nutrient supply were found to promote root formation without affecting fruit size (Table 3) and fruit quality (data not shown). Taken together, by using the above-mentioned strategies, we successfully obtained efficient rooting in fruit-bearing canes via air layering in kiwifruit (Fig. 3).

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REFERENCES

Abbate, A. P., Campbell, J. W., Vinson, E. L., & Williams, G. R. (2021). The pollination and fruit quality of two kiwifruit cultivars (*Actinidia chinensis* var. chinensis 'AU Golden Sunshine'and 'AU Gulf Coast Gold') (Ericales: Actinidiaceae) grown in the southeastern United States. *Journal of Economic Entomology*, *114*(3), 1234-1241.

Black, M. Z., Minchin, P. E., Gould, N., Patterson, K. J., & Clearwater, M. J. (2012). Measurement of bremsstrahlung radiation for *in vivo* monitoring of 14C tracer distribution between fruit and roots of kiwifruit (*Actinidia arguta*) cuttings. *Planta*, *236*(4), 1327-1337.

Cristofori, V., Rouphael, Y., & Rugini, E. (2010). Collection time, cutting age, IBA and putrescine effects on root formation in *Corylus avellana* L. cuttings. *Scientia Horticulturae*, *124*(2), 189-194. https://doi.org/https://doi.org/10.1016/j.scienta.2009.12.034

El-Banna, M. F., Farag, N. B., Massoud, H. Y., & Kasem, M. M. (2023). Exogenous IBA stimulated adventitious root formation of *Zanthoxylum beecheyanum* K. Koch stem cutting: Histo-physiological and phytohormonal investigation. *Plant Physiology and Biochemistry*, *197*, 107639.

Erturk, Y., Ercisli, S., Haznedar, A., & Cakmakci, R. (2010). Effects of plant growth promoting rhizobacteria (PGPR) on rooting and root growth of kiwifruit (*Actinidia deliciosa*) stem cuttings. *Biological Research*, *43*(1), 91-98. WOS:000276887500011

Hazarika, B., Angami, T., & Parthasarathy, V. (2022). Kiwifruit. In: Daya Publishing House, Delhi, India.

İşçi, B., Kacar, E., & Altindiþli, A. (2019). Effects of IBA and plant growth-promoting rhizobacteria (PGPR) on rooting of Ramsey American grapevine rootstock. *Applied Ecology & Environmental Research*, *17*(2), 4639-4705.

Lakho, M. A., Jatoi, M. A., Solangi, N., Abul-Soad, A. A., Qazi, M. A., & Abdi, G. (2023). Optimizing *in vitro* nutrient and *ex vitro* soil mediums-driven responses for multiplication, rooting, and acclimatization of pineapple. *Scientific Reports*, *13*(1), 1275.

Li, D., Han, F., Liu, X., Lv, H., Li, L., Tian, H., & Zhong, C. (2021). Localized graft incompatibility in kiwifruit: analysis of homografts and heterografts with different rootstock & scion combinations. *Scientia Horticulturae*, *283*, 110080.

Wu, Y., Liu, J., Sheng, X., Wang, W., Wang, T., Martinez-Sanchez, M., Wang, S., Tu, M., Deng, J., Allan, A., Atkinson, R., Nieuwenhuizen, N. J., Yin, X., Zeng, Y. (2025). Spatial regulation of chlorophyll degradation in kiwifruit: AcNAC2-AcSGR1/2 cascades mediate rapid de-greening in the inner pericarp. *Plant Biotechnology Journal*, *23*, 2554–2569.

Mao, J. P., Zhang, D., Zhang, X., Li, K., Liu, Z., Meng, Y., Lei, C., Han, M. Y. (2018). Effect of exogenous indole-3-butanoic acid (IBA) application on the morphology, hormone status, and gene expression of developing lateral roots in *Malus hupehensis*. *Scientia Horticulturae*, *232*, 112-120. doi: 10.1016/j.scienta. 2017.11.026

Martini, A., & Papafotiou, M. (2007). *In vitro* rooting of *X Malosorbus florentina* Zucc. microshoots. VI International Symposium on New Floricultural Crops, 813.

Mellidou, I., & Karamanoli, K. (2022). Unlocking PGPR-mediated abiotic stress tolerance: what lies beneath. *Frontiers in Sustainable Food Systems*, *6*.

Mi, T., Luo, D., Li, J., Qu, G., Sun, Y., & Cao, S. (2023). Carvacrol exhibits direct antifungal activity against stem-end rot disease and induces disease resistance to stem-end rot disease in kiwifruit. *Physiological and Molecular Plant Pathology*, *127*, 102065. https://doi.org/https://doi.org/10.1016/j.pmpp.2023.102065

Mullins, M. G., & Rajasekaran, K. (1981). Fruiting cuttings: revised method for producing test plants of grapevine cultivars. *American Journal of Enology and Viticulture*, *32*(1), 35-40. https://doi.org/10.5344/ajev.1981.32.1.35

Rana, V. S., & Kumar, G. (2021). Kiwifruit. In *Temperate Fruits* (pp. 417-448). Apple Academic Press.

Rymbai, H., Talang, H., Dayal, V., Deshmukh, N., Assumi, S., Devi, M., & Jha, A. (2022). Kiwifruit - A high-value crop for hilly terrain. *Today & Tomorrow's Printers and Publishers, New Delhi*.

Xie, M., Jiang, Y., Xu, K., Guo, W., & Yuan, T. (2023). Strangulation and IBA treatments as an effective method to propagate tree peonies, *Paeonia suffruticosa*. *Scientia Horticulturae*, *307*, 111487.

Zhong, C., Wang, Z., & Bu, F. (2002). 'Fengyue' and 'Cuiyu', two superior new kiwifruit cultivars with good storage quality. *Acta Horticulturae Sinica*, *29*(6), 592-592. https://eurekamag.com/research/003/616/003616295.php

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