

Establishment of the Rapid Propagation System of *Actinidia arguta*

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Abstract

The effects of different growth regulator types and ratios on the induction of adventitious shoots and adventitious roots were investigated using *Actinidia arguta* leaves as materials. 'Purple Sadova' was found to have strong germination and the highest germination rate on induction media with different *PGRs* concentrations. In this experiment, the best medium for the induction of adventitious shoots was MS + ZT 3.0 mg·L⁻¹ + NAA 0.1 mg·L⁻¹, with a germination rate of 36.67%. The most suitable site for the induction of adventitious shoots was the base of the leaves, with a germination rate of 80.00%. The longer the dark culture time was, the more suitable for adventitious bud germination, and the germination rate of adventitious buds reached 80.00% after 30 d of dark culture. The best proliferation medium for adventitious buds was MS + 6-BA 1.0 mg·L⁻¹ + NAA 0.3 mg·L⁻¹, with a proliferation coefficient of 3.57. The proliferated buds had strong growth potential, large leaves, green color and high buds. The best rooting medium was 1/2MS + IBA 0.7 mg·L⁻¹, with 100% rooting rate, average root length of 2.81 cm and average root number of 14.5. In conclusion, this study explored an effective method to improve the quantity and quality of reproduction of this *A. arguta*, enriched the fast breeding system of *A. arguta*, and provided a theoretical basis for the factory breeding of all-red type *A. arguta* seedlings.

Introduction

The *Actinidia arguta*, also known as the kiwi berry, belonging to the basal genus *Actinidia* within the family *Actinidiaceae*, and is native to China (Latocha et al., 2017; Huang et al., 2000). It has been domesticated since the 1990s and is the third generation of emerging dual-use fruit because of its hairless surface, sweet and sour fruit, rich nutritional value, and ease of consumption.

At present, *A. arguta* is abundant, in its natural growing state, it is difficult to meet the growing consumer demand for the fruit. Firstly, in its natural state, the *A. arguta* has a large variation in the number of fruits produced each year, making it difficult to guarantee a stable supply of fruit., and the chemical composition of *A. arguta* is heterogeneous, with genetic variability and many environmental factors (such as soil fertility, water availability, temperature, and sunlight) that may affect the chemical and nutritional characteristics of this fruit (Latocha et al., 2015; Latocha et al. 2013). Thus, the artificial domestication of the *A. arguta* and the development of a range of related products is an inevitable trend of the times (Pu et al., 2009). Current commercial kiwifruit varieties are mostly *A. chinensis* and *A. deliciosa*, as well as *A. arguta* and *A. eriantha*. But the *A. arguta* variety is still rare compared to the *A. chinensis* and *A. deliciosa* (Wu et al., 2021). Compared with *A. chinensis* and *A. deliciosa*, *A. arguta* do not need to be post-ripened and can be eaten directly with the peel (Lin et al., 2016; Szpadzik et al., 2021). In terms of nutritional value, the fruit of the *A. arguta* has high levels of antioxidants, particularly vitamin C (22-1530 mg/100 g), phenolic compounds (200–362 mg GAE/100 g), vitamin E (4.3–5.3 mg/100 g), β-carotene (0.22–0.29 mg/100 g) and lutein (0.75–0.93 mg/100 g) (Latocha et al., 2015). In terms of nutritional value, *A. arguta* already surpasses the vast majority of fruits. For the past few decades, the majority of kiwis on the world market have been green-fleshed fruits, suggesting that the global commercial market has been dominated by green-fleshed kiwifruit varieties, such as the most famous New Zealand-bred variety 'Hayward'. However, over the past few years, red-fleshed kiwis with high levels of anthocyanins have become increasingly sought after by consumers for their antioxidant properties and health benefits (He et al., 2010). The taste of the fruit is usually best in red, followed by yellow and green (Qi et al., 2011). 'Purple Sadova' is an all-red *Actinidia arguta* with red skin and flesh, which has a high nutritional and ornamental value.

The all-red *A. arguta* has grown rapidly in ecological agriculture in recent years with the development of tourist gardens and picking gardens and has wide market potential, thus the requirement for a significant number of seedlings for production. The majority of the production is done through standard seed planting, cuttings, and grafting. Extended growth cycles, unstable offspring traits, easy trait segregation, late blooming and fruiting, and long growth cycles are characteristics of seed propagation (Abraham et al., 2009). *A. arguta* cuttings, particularly younger shoots with large leaves and long petioles, are clipped in cutting propagation with a third of the leaves removed, making the cuttings' leaves susceptible to physiological and invasive diseases that hinder roots (Huang et al., 2010; Long et al., 2010). Cuttings usually don't live as long as plants grown in other ways, and their survival rate is significantly impacted by the seasons as well as strict environmental demands. With some seasonal limitations, grafting is typically used as a technique of propagation for *A. arguta*. The grafting site is vulnerable to disease, and whenever one party has a virus during the grafting process, the virus will be present in the grafted fruit tree (Liu et al., 2021; He et al., 2012). One of the major techniques for growing seedlings is tissue culture, which has the advantages of being freed from time- and space-based constraints and possessing the capacity to quickly produce a large number of seedlings of great quality (Uchendu et al., 2011; Qi et al., 2004). According to prior studies, 6-BA was principally used as a cytokinin to induce *A. arguta*, while NAA, IBA, and IAA were used as auxin (Liu et al., 2013; Guo et al., 2014; Xie et al., 2003). Most of the varieties studied were green-fleshed *A. arguta*, while few studies on fast breeding of the all-red type of *A. arguta* have been reported (Wang et al., 2018; Lin et al., 2016). However, the larger kiwifruit has been used as the source of sample material for the majority of studies. Studies on fruit pigmentation have focused on the slightly red-fleshed "Hongyang" fruit (Li et al. 2015), however, it is rare to find similar studies on fully red-fleshed kiwifruit fruit (Li et al., 2018).

Therefore, in this experiment, the best plant growth regulator ratios for each stage of adventitious shoot germination, adventitious shoot proliferation and adventitious shoot rooting were screened using the leaves of the all-red *A. arguta* 'Purple Sadova' as the material. A fast breeding system for all-red *A. arguta* was established to provide a theoretical basis for the development and utilization of all-red *A. arguta* and excellent varieties and factory nursery.

Materials And Methods

Induction culture of adventitious shoots

Micropropagated 'Purple sadova', 'Wiki', and 'Red September' plantlets were cultivated in a growth chamber at $(25 \pm 2) ^\circ\text{C}$ on MS solid medium supplemented with $30 \text{ g}\cdot\text{L}^{-1}$ sucrose, $7 \text{ g}\cdot\text{L}^{-1}$ agar and $\text{pH} = 5.8$. The light intensity varied between 2000 and 3000 Lux with a 16-hour light and 8-hour dark cycle. Five-week-old seedlings were used as explants. Select the sterile leaves of 'Wiki', 'Purple Sadova,' and 'Red September,' cut them into $0.5 \text{ cm} \times 0.5 \text{ cm}$ leaf blocks, and inoculate them into MS regeneration culture containing various concentrations of ZT and NAA. The inoculation of 10 explants per flask at the base was repeated three times for a total of 30 explants per treatment. After 30 days of dark culture, the sample was moved to light culture, and after 60 days, statistics were recorded. All the following temperature and light conditions are the same as above.

The leaves of 'Purple Sadova' sterile seedlings were divided into three parts: leaf base, leaf middle and leaf tip, and the leaves of each part were cut into $0.5 \text{ cm} \times 0.5 \text{ cm}$ leaf pieces and inoculated onto MS medium containing $7 \text{ g}\cdot\text{L}^{-1}$ agar, $30 \text{ g}\cdot\text{L}^{-1}$ sucrose, $3.0 \text{ mg}\cdot\text{L}^{-1}$ ZT and $0.1 \text{ mg}\cdot\text{L}^{-1}$ NAA, and pH adjusted to 5.8. Six explants were inoculated per vial, replicated five times, with a total of 30 explants per treatment. After 30 d of dark culture, the culture was transferred to light culture, and rate of the number of buds and germination rate were counted after 60 d.

The leaf bases of sterile seedlings of 'Purple Sadova' were cut into 0.5 cm × 0.5 cm leaf pieces and inoculated onto MS medium containing 7 g·L⁻¹ agar, 30 g·L⁻¹ sucrose, 3.0 mg·L⁻¹ ZT and 0.1 mg·L⁻¹ NAA, and pH adjusted to 5.8. 6 explants were inoculated per vial and replicated 5 times with a total of 30 explants per treatment. After different dark culture times (0,7,14,21,30 d), the culture was transferred to light culture and the number of buds and germination rate were counted after 60 d.

Adventitious shoot multiplication culture

Adventitious shoots of approximately 3 cm in height caused by the primary culture were moved to a blank MS medium for 15 days before being transferred to a proliferation medium of MS + 30 g·L⁻¹ sucrose + 7.5 g·L⁻¹ agar + *PGRs* (Table 1), pH adjusted to 5.8. Three explants were inoculated in each vial and replicated 10 times for a total of 30 explants per treatment. The culture conditions were the same as described previously.

Table 1
PGRs ratio of multiplication culture

Processing number	6-BA (mg·L ⁻¹)	NAA (mg·L ⁻¹)	GA ₃ (mg·L ⁻¹)
1	1	0.1	0.1
2	1	0.3	0.1
3	1	0.5	0.1
4	2	0.1	0.1
5	2	0.3	0.1
6	2	0.5	0.1

Rooting culture

3 cm tall seedlings were inoculated onto MS + 30 g·L⁻¹ sucrose + 7 g·L⁻¹ agar + IBA (0, 0.3, 0.5, 0.7, 1.0 mg·L⁻¹), pH adjusted to 5.8. Each bottle was inoculated with one explant, replicated 30 times, with a total of 30 explants per treatment. The cultural conditions remained unchanged.

Seedling transplanting

The rooted seedlings were acclimatized, open the mouth of the bottle, pour 1 cm high sterile water, cover three-quarters of the bottle with a cap for 7 d; remove the seedlings in the bottle, wash the root medium, transplant in coconut coir: perlite = 7:3 substrate, water the cavity tray thoroughly with tap water for the first time, put the tray under the cavity tray, add 1000 times diluted nutrient solution to the tray, cover the top with a moisturizing cap The second transplanting could be done after 30 d.

Data statistics and analysis

The germination rate (%) = Number of germinated adventitious buds / The number of inoculation × 100%

Proliferation coefficient = The number of adventitious shoots after proliferation / The number of inoculation

Rooting rate (%) = Number of rooted seedlings/number of inoculated seedlings × 100%

Rate of callus formation (%) = The number of callus formation/The number of inoculation × 100%

Data were processed using Excel 2016 software and SPSS 20.0 for statistical analysis.

Results

Effects of different genotype on adventitious bud regeneration

As shown in Table 2, the rate of callus formation of the three varieties exhibited a consistent trend; as the concentration of ZT increased, the rate of callus formation decreased for all three varieties; however, when ZT was maintained at a high concentration, thereby increasing the concentration of NAA, the rate of callus formation once again exhibited an increasing trend. However, the germination rates of the three varieties exhibited different trends; the germination rates of 'Wiki' and 'Purple Sadova' increased with increasing ZT concentrations, 'Wiki' had the maximum germination rate of 23.67% on 3 mg·L⁻¹ ZT + 0 mg·L⁻¹ NAA and 'Purple Sadova' had the maximum germination rate of 36.67% on 3 mg·L⁻¹ ZT + 0.1 mg·L⁻¹ NAA. The germination rate of Red September decreased with increasing ZT concentration, with the highest value reaching 16.67% at 1 mg·L⁻¹ ZT + 0.1 mg·L⁻¹ NAA. As illustrated in Fig. 1, the genotypes of *A. arguta* generated a range of adventitious shoots of varying quality, with 'Wiki' and 'Purple Sadova' outperforming "Red September" in yield. 'Red September' has the ability to regenerate a single bud, and a single callus results in a single indefinite bud. 'Wiki' and 'Purple Sadova' have the potential to regenerate cluster buds, and a single callus can result in numerous indefinite buds. Therefore, it can be concluded that the regeneration rate of 'Purple Sadova' leaves was highest under the medium of 3 mg·L⁻¹ ZT + 0.1 mg·L⁻¹ NAA and the best regeneration of adventitious shoots, so 'Purple Sadova' and this hormone ratio were chosen for the subsequent study.

Table 2
Effects of different genotype on adventitious bud regeneration

ZT(mg·L ⁻¹)	NAA(mg·L ⁻¹)	Rate of callus formation(%)			Germination rate(%)		
		'Wiki'	'Purple Sadova'	'Red September'	'Wiki'	'Purple Sadova'	'Red September'
1	0	100	66.67	80	0 f	6.67 def	10 cde
1	0.1	100	100	100	0 f	0 f	16.67 bc
1	0.2	66.67	100	86.67	10 cde	0 f	0 f
2	0	40	50	80	13.33 cd	13.33 cd	6.67 def
2	0.1	100	100	100	0 f	13.33 cd	3.33 ef
2	0.2	10	100	100	13.33 cd	3.33 ef	0 f
3	0	33.33	13.33	26.67	23.67 b	16.67 bc	0 f
3	0.1	20	53.33	36.67	3.33 ef	36.67 a	0 f
3	0.2	50	60	100	0 f	0 f	0 f

Note: Different lowercase letters at the end of data in the same column indicate significant difference ($P < 0.05$). The following table is the same.

The leaves were inoculated on regeneration medium for about 15 d (Fig. 2, a), the leaves began to expand and curl, and there was a small amount of callus at the edge of the leaves, after 30 d of inoculation (Fig. 2, b), a large amount of white callus was observed, the texture of the callus was fluffy, then it was transferred to light culture and cultured for 7 d in the light (Fig. 2, c ~ f), the texture of the callus became compact from fluffy, and the color changed to bright green, meanwhile, a After 25 d of light culture (Fig. 2, f), adventitious buds could be observed, and with the extension of culture time, the buds gradually developed into a cluster of small plants, and after 45 d of light culture, the adventitious buds were no longer produced and some of the callus began to brown.

Effect of different parts of leaf on adventitious shoots regeneration of 'Purple Sadova' leaves

As can be seen from Table 3, as the physiological state of the explants became older, the rate of callus formation, germination rate and average number of shoots were decreasing, with the highest germination rate and average number of shoots at the base of the leaf blade, 80.00% and 16, respectively, and the lowest germination rate and average number of shoots at the tip of the leaf blade, 36.67% and 5, respectively. The difference in germination rate between the base of the leaf and the middle of the leaf was not significant, but the difference between the germination rate of these two parts and the germination rate of the tip of the leaf both reached a significant level, and the average number of germination of these two parts was 3 times and 2 times of the average number of germination of the tip of the leaf, respectively. In the experiment, it was also observed that the germination time of different leaf parts was different, and the buds could be seen at the base of the leaf in 7 d of light culture, while the middle of the leaf took about 10 d and the tip of the leaf took 15 d. Meanwhile, it was found that the quality of regenerated buds was different in different parts, and the regenerated buds at the base of the leaf had the highest quality, and most of the regenerated buds could grow into robust seedlings in a short time, while the regenerated buds at the tip of the leaf had the worst quality. Most of the buds observed stop growing and then die, although they have an intact structure. Therefore, the base of the leaf is the most desirable explant for the in vitro regeneration of 'Purple Sadova' leaves.

Table 3
Effect of different parts of the leaf on the regeneration of adventitious shoots of 'Purple Sadova' leaves

Leaf parts	The number of inoculation	Rate of callus formation	Germination rate	Average number of buds
Blade base	30	93.33%	80.00% a	16
Middle of the blade	30	90.00%	70.00% a	11.6
Blade tip	30	86.67%	36.67% b	5

Effect of different dark culture times on adventitious bud regeneration of 'purple Sadova' leaves

At 7 d after inoculation, it was observed that there was a majority of browning and death of the explants without dark culture; meanwhile, it was found that early light culture did not affect the germination time. As shown in Table 4, the dark culture of explants had an effect on the healing rate, germination rate and average germination number of explants, and the germination rate and average germination number increased with the extension of dark culture time, and the highest germination rate was 80.00% at 30 d of dark culture time, and the difference with other treatments reached a significant level. Therefore, the optimal dark culture time was 30 d.

Table 4
Effect of different dark culture times on adventitious bud regeneration of 'purple Sadova' leaves

Dark culture time/d	The number of inoculation	Rate of callus formation	Germination rate	Average number of buds
0	30	43.33%	13.33% d	2.6
7	30	73.33%	23.33% cd	2
14	30	100.00%	33.33% c	5.4
21	30	80.00%	60.00% b	11.4
30	30	93.33%	80.00% a	16

Effect of 6-BA and NAA on the proliferation of adventitious shoots of 'Purple Sadowa'

The axillary bud tips at the base of the seedlings developed after 12 days of inoculation, but no new seedlings sprouted after 20 days. During the same experiment, it was noticed that adventitious shoots of *A. arguta* were beginning to grow from the axillary buds (Fig. 4a). According to Table 5, treatments 5 and 6 had considerably greater fresh weights than treatments 1 through 4. This is likely owing to a substantial amount of callus formation, which encased the original seedlings, inhibiting their growth and resulting in fewer shoots proliferating. Meanwhile, Some of the shoots in treatments 5 (Fig. 3e) and 6 (Fig. 3f) displayed malformed leaves with narrow leaves and sharply serrated margins, and they grew excessively long and thin. In treatment 3 (Fig. 3c), a 1:1 ratio of NAA to 6-BA was detected, which is optimum for callus growth but detrimental for shoot proliferation. The difference between the overall proliferation coefficients of treatments 1, 2, and 4 was not significant, although treatment 4 (Fig. 3d) resulted in shorter adventitious shoots than the other two treatments. Additionally, the proliferation coefficient of treatment 4 with plant height > 2 cm was significantly different from treatments 1 (Fig. 3a) and 2 (Fig. 3b), whereas the difference between treatments 1 and 2 was not significant, and the seedlings proliferated from both treatments grew vigorously, with taller plants and larger leaves. Therefore, both treatments 1 and 2 are acceptable for adventitious shoot proliferation.

Table 5
Effects of 6-BA and NAA on adventitious shoot proliferation of 'Purple Sadowa'

Processing number	The number of inoculation	The total fresh weight/g	The total dry weight/g	Total proliferation number	The proliferation number with a plant height > 2cm	Total proliferation coefficient	Proliferative coefficient of plant height > 2cm
1	30	27.99	2.41	101	74	3.37 ± 0.25a	2.46 ± 0.32 a
2	30	28.78	2.66	107	70	3.57 ± 0.23a	2.33 ± 0.25 ab
3	30	28.83	2.81	76	32	2.53 ± 0.45b	1.11 ± 0.19 d
4	30	26.23	2.44	110	45	3.67 ± 0.23a	1.50 ± 0.36 c
5	30	56.00	5.09	86	69	2.87 ± 0.33b	2.16 ± 0.37 b
6	30	65.92	6.04	78	44	2.60 ± 0.31b	1.47 ± 0.27 c

Effect of IBA on the rooting of 'Purple Sadowa' seedlings

At 4 days after inoculation, the seedlings began to generate callus at the base, a few seedlings began to root at 7 days, the majority of seedlings began to root around 10 days, and after 20 days, no new roots emerged, the roots only became longer (Fig. 4b and c). As the concentration of IBA grew, the amount of callus at the seedlings' bases increased. As can be seen from Table 4, IBA promoted the rooting of seedlings, and the rooting rate of medium with IBA was higher than that of medium without IBA, and the average number of roots increased with the increase of IBA concentration, and the average number of roots differed significantly between treatments with different IBA concentrations, and the rooting rate and average number of roots of medium without IBA were the lowest, 83% and 3.96, respectively; When IBA was $1.0 \text{ mg}\cdot\text{L}^{-1}$, the maximum number of roots was 17.60, but the rooting rate was only 89%; when IBA was $0.5 \text{ mg}\cdot\text{L}^{-1}$ and $0.7 \text{ mg}\cdot\text{L}^{-1}$, the rooting rate reached 100%, and the average number of roots was 7.60 and 14.50, respectively, and the average number of roots of the latter was significantly higher than that of the former. The total fresh weight of seedlings also increased with the increase of IBA concentration, while in the treatment of IBA at $1.0 \text{ mg}\cdot\text{L}^{-1}$ (Fig. 5e), a large number of callus grew at the base of seedlings, resulting in a much higher total fresh weight than the other treatments. Considering the rooting rate, average root number and average root length, the optimal IBA rooting concentration was $0.7 \text{ mg}\cdot\text{L}^{-1}$.

Table 6
Effects of IBA on rooting of 'purple Sadowa' seedlings

IBA/(mg·L ⁻¹)	The number of inoculation	The number of rooting trees	Rooting rate	The average plant height/cm	The average number of roots	The average root length/cm	The total fresh weight/g	The total dry weight/g
0	30	25	83%	4.32 ± 0.63	3.96 ± 1.23e	3.29 ± 0.38ab	9.86	1.02
0.3	30	30	100%	4.11 ± 0.69	5.90 ± 1.30d	3.07 ± 0.61b	14.22	1.45
0.5	30	27	89%	4.21 ± 0.74	7.60 ± 1.74c	2.94 ± 0.85bc	17.45	1.79
0.7	30	30	100%	4.00 ± 0.78	14.50 ± 1.69b	2.81 ± 0.42c	17.85	1.98
1.0	30	27	89%	4.08 ± 0.57	17.60 ± 1.56a	3.40 ± 0.53a	28.72	2.94

Transplanting

After acclimatization, the seedlings were withdrawn from the vials, the root media rinsed, and the seedlings were transplanted into a substrate consisting of 7:3 coconut coir: perlite. The pots were properly watered with tap water for the first time, trays with a 1000-fold diluted nutrient solution were placed beneath the pots, and the pots were covered with a moisturizing lid to keep them hydrated. All of the seedlings survived and thrived (Fig. 4d).

Discussion

In plant tissue culture, the type of plant growth regulator and the concentration ratios employed are crucial criteria for experiment success (Piao et al., 2011). In this experiment, it was found that when the 6-BA concentration was 2.0 mg·L⁻¹, deformed seedlings appeared, indicating that 'Purple Sadowa' was more sensitive to 6-BA and could tolerate lower concentrations of 6-BA, and the optimal plant growth regulator concentrations in the proliferation medium were 1.0 mg·L⁻¹ 6-BA with 0.1 mg·L⁻¹ NAA or 0.2 mg·L⁻¹ NAA for a total proliferation coefficient greater than 3. Hu et al. (2011) used 'Kui Green' as the material and added 6-BA and IBA to the medium to get a proliferation coefficient of 5.8; Deng (2017) utilized 'Longcheng 2' as the material and added 6-BA and IBA to achieve a proliferation coefficient of 5.8. This experiment's total proliferation coefficient was lower than that of prior research, perhaps due to the differential between NAA and IBA. The optimal IBA concentration for rooting 'Purple Sadowa' was found to be 0.7 mg·L⁻¹, which is largely comparable with earlier findings (Yu et al., 2014). The physiological state of explants is different, the effect of in vitro regeneration is also different, the younger the explants the better the in vitro regeneration effect. Different parts of the leaf have different physiological states. Many studies have shown that the base of the leaf is the youngest and the tip of the leaf has the oldest physiological state, so the base of the leaf is the ideal explant for in vitro regeneration (Guan., 2014). According to studies on *Lachenalia* (Niederwieser et al., 1990), blueberries (Billings et al., 1988), pears (Chevreau et al., 1989), and apples (Fasolo et al., 1989; Baker et al., 1993), dark culture promotes morphogenesis and organ creation. Hangarter et al. (1991) have demonstrated that growth hormone degrades more slowly under dark culture conditions, which simplifies the control of the ratio of growth hormone to cytokinin in the explants.

The *A. arguta* is an emerging tiny berry with high economic benefits and extensive market potential (Latocha et al., 2017). With the expansion of industrial *A. arguta* agriculture, the need for its good seedlings is progressively growing, and the construction of a regeneration system for the *A. arguta* is a vital solution to this problem. However, the complex genetic background of *A. arguta* makes plant regeneration difficult, and regeneration systems have only been established on a few varieties, and the regeneration rates obtained are not high, lacking a stable and efficient regeneration system. Through this study, effective methods to improve the quantity and quality of *A. arguta* reproduction were explored, enriching the fast breeding system of *A. arguta*, providing a theoretical basis for the factory breeding of all-red *A. arguta* seedlings, reducing breeding costs, making them better used in food and pharmaceutical industries, and increasing the use value and economic benefits of *A. arguta*; and providing a large amount of high-quality material for research on genetic transformation systems, disease resistance, micro-grafting techniques, etc. The subsequent step will be to investigate the optimal growth conditions for transplanted seedlings to make sure their quality, and to use this *A. arguta* to establish an efficient genetic transformation system to provide technical support for gene function analysis and genetic improvement of the *A. arguta*.

Declarations

CRedit authorship contribution statement

Wantian Yao: Writing - original draft, Visualization; **Lingling Kong:** Investigation, Methodology, Data curation; **Diya Lei:** Investigation, Validation; **Bing Zhao:** Methodology, Validation; **Honglan Tang:** Software, Methodology; **Xuan Zhou:** Investigation, Methodology; **Yuanxiu Lin:** Formal analysis; **Yunting Zhang:** Investigation; **Qing Chen:** Software; **Yan Wang:** Visualization; **Mengyao Li:** Investigation; **Wen He:** Investigation; **Ya Luo:** Visualization; **Xiaorong Wang:** Visualization; **Haoru Tang:** Project administration; **Yong Zhang:** Writing - review & editing, Conceptualization, Funding acquisition.

Declaration of Competing Interest

All authors declare that they have no conflict of interest.

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Figures

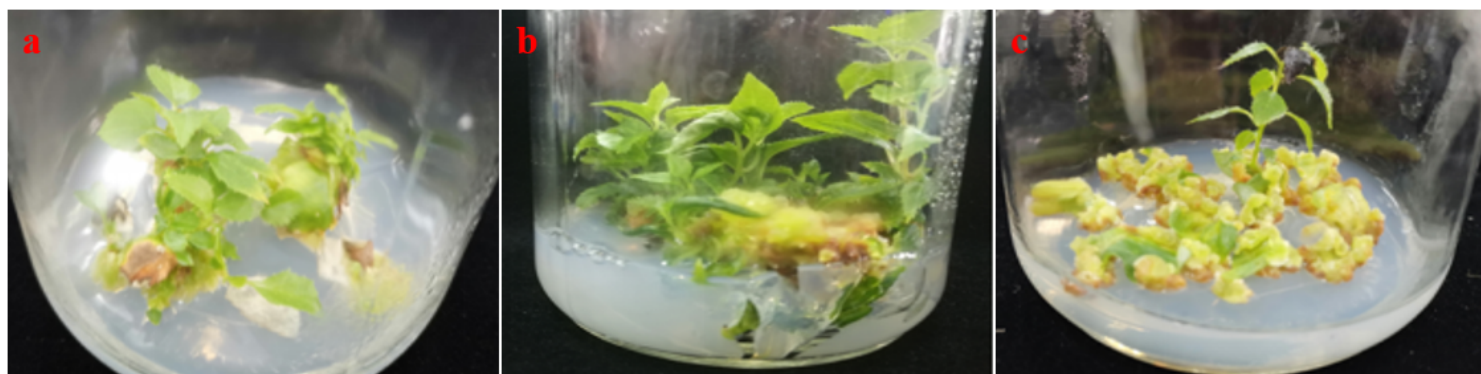


Figure 1

Regeneration of *A. arguta* leaves of different genotypes (a: Wiki; b: Purple Sadova; c: Red September)

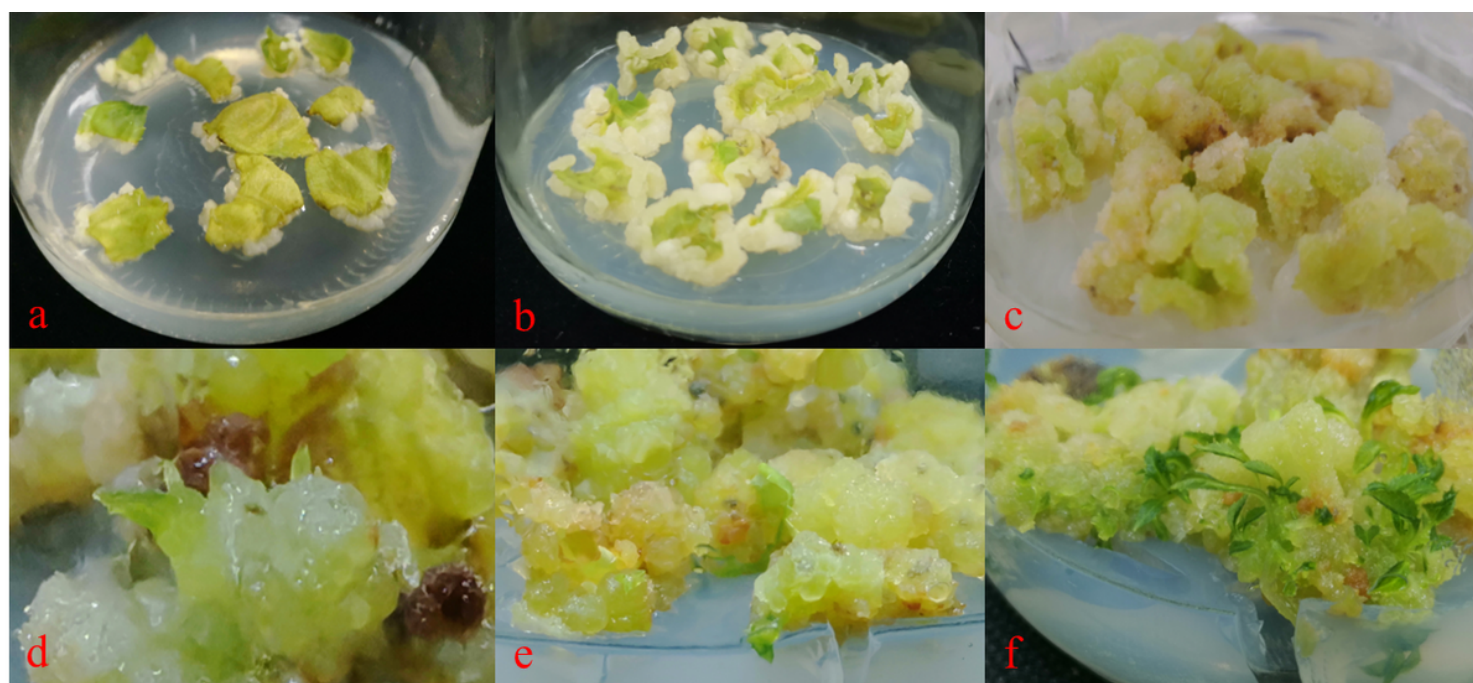


Figure 2

Regeneration of adventitious shoots from 'Purple Sadova' leaves (a: dark culture for 15 d after inoculation; b: dark culture for 30 d after inoculation; c~e: light culture for 7 d (37 d after inoculation); f: light culture for 25 d (55 d after inoculation))

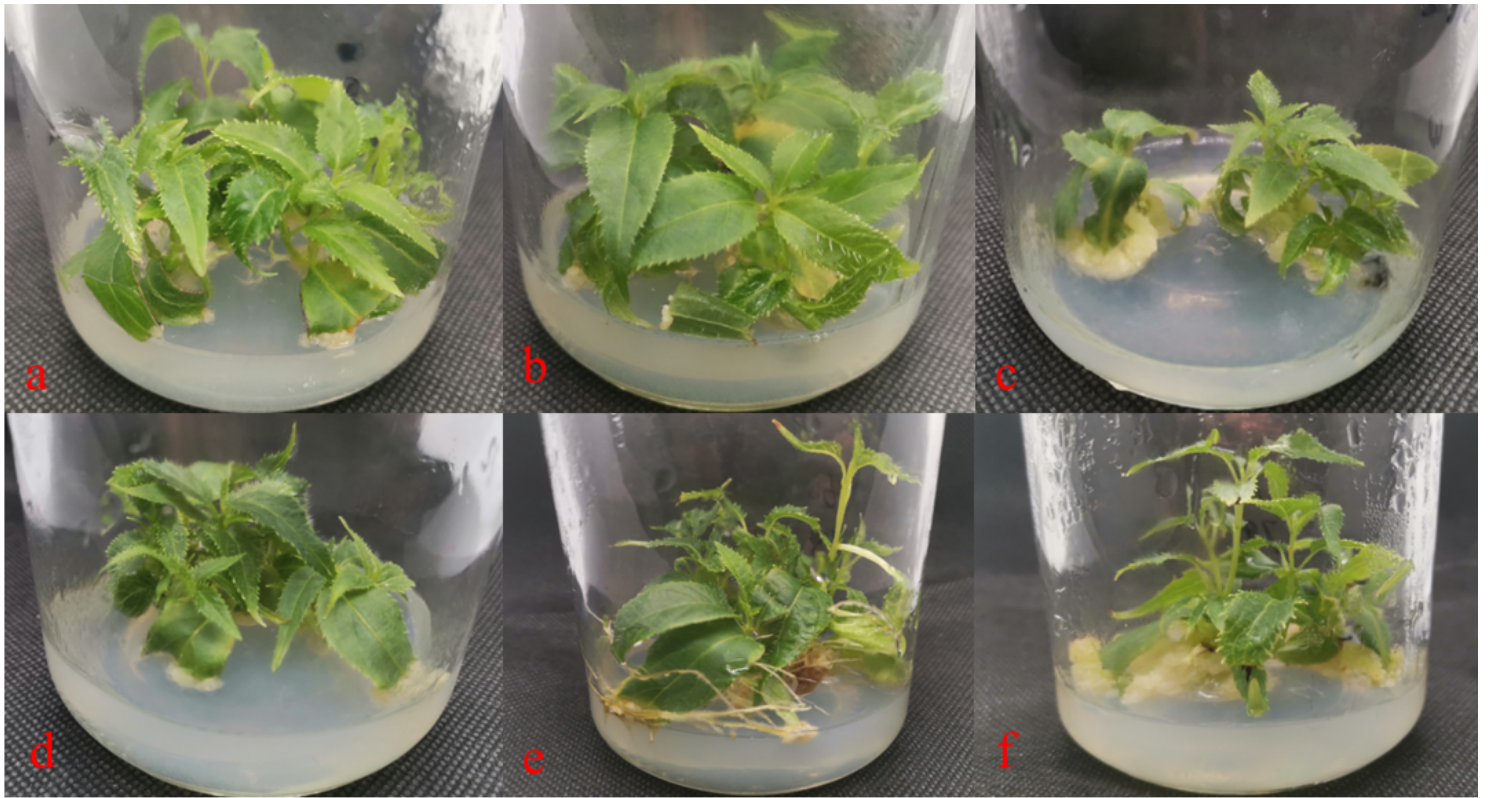


Figure 3

Adventitious shoot proliferation of 'Purple Sadowa' (a: processing number 1; b: processing number 2; c: processing number 3; d: processing number 4; e: processing number 5; f: processing number 6)

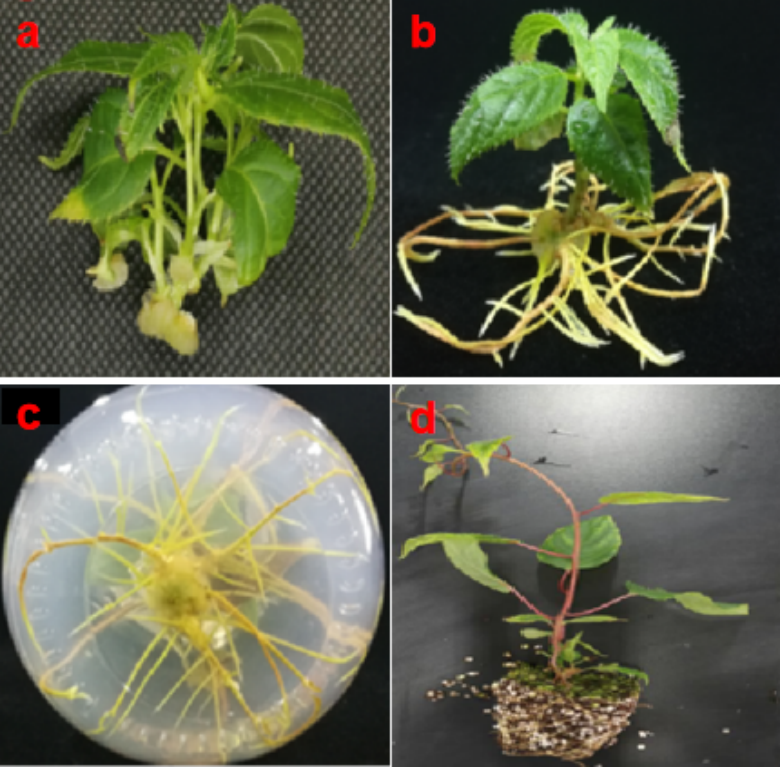


Figure 4

Rapid propagation of Kiwifruit 'Purple Sadowa' (a Adventitious bud proliferation b c seedling rooting d transplanting for 30days)



Figure 5

Effects of IBA on rooting of 'purple Sadowa' seedlings (a: 0 mg·L⁻¹ IBA; b: 0.3 mg·L⁻¹ IBA; c: 0.5 mg·L⁻¹ IBA; d: 0.7 mg·L⁻¹ IBA; e: 1.0 mg·L⁻¹ IBA)