

生长调节剂和柠檬酸处理对柿砧木嫩枝扦插生根的影响

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摘要:【目的】探究生长调节剂和柠檬酸处理对柿砧木嫩枝扦插生根的影响, 找出促进柿砧木嫩枝扦插生根的适宜方法。【方法】以君迁子L938和泰富为材料, 设置不同药剂及浓度、砧木类型、新梢部位及扦插时期等处理, 测定不同处理对柿嫩枝扦插生根的影响。【结果】以3000 mg·L⁻¹IBA+NAA速蘸或0.4%(φ , 后同)柠檬酸浸泡插穗基部, 生根率最高; 柿不同砧木类型(君迁子、本砧)嫩枝扦插生根率无显著差异; L938新梢不同部位扦插生根率没有明显差异; 2种砧木插穗5月中旬扦插生根率均显著高于7月中旬。【结论】5月中旬以砧木新梢中上部作插穗, 留顶叶1/4~1/2, 基部用3000 mg·L⁻¹的IBA+NAA速蘸50 s或用0.4%的柠檬酸浸泡2 h扦插于蛭石中, 全光照弥雾条件下, 生根率可超过77%。

关键词:柿砧木; 嫩枝扦插; 生长调节剂; 柠檬酸; 生根率

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Effect of plant growth regulators and citric acid on the rooting of soft-wood cuttings of persimmon rootstocks

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Abstract:【Objective】Persimmon (*Diospyros kaki* Thunb.) is one of the important fruit tree species in our country. In recent years, pollination-constant non-astringent (PCNA) persimmons has gradually become the key development type in persimmon industry. Field practice in the past few years has shown that L938 (*Diospyros lotus* L.) and Taifu (*Diospyros kaki* Thunb.) are ideal rootstocks for PCNA persimmon in consideration of their wide compatibility and strong cold resistance in northern China. However, the scale application is difficult to achieve because of the scarcity of materials. Cutting propagation would be an effective way to solve this problem. Therefore, the object of this study was to explore the effects of plant growth regulators and citric acid treatments on the rooting of softwood cuttings of persimmon rootstocks and find a suitable rooting method. 【Methods】The experiment was carried out in the scientific research base of Hebei Agricultural University from 2019 to 2020. Plant materials L938 and Taifu were planted in the research base. There were 5 sections in this study: 1) Taifu cuttings were treated with 1000, 2000, 3000, 4000, 5000 mg·L⁻¹IBA+NAA mixed reagent (1:1), and 0.1%, 0.2%, 0.3%, 0.4%, 0.5% citric acid solution or water (CK), then inserted into nutrient cups filled with cutting medium; 2) Based on the first section, Taifu cuttings were treated with 3000 mg·L⁻¹IBA+NAA mixed reagent or 0.4% citric acid solution respectively; 3) Different rootstock cuttings Taifu and L938 were

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treated with $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA mixed reagent or 0.4% citric acid solution, respectively; 4) L938 cuttings were divided into 2 parts (the upper side and the middle part) before being cut into segments. Then the segments were treated with $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA mixed reagent or 0.4% citric acid solution respectively; 5) Taifu and L938 cuttings were firstly treated with $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA mixed reagent or 0.4% citric acid solution, and then the cutting test was carried out in May and July, respectively. Water treatment was used as the control in all experiments. The root length, rooting rate and rooting number of the cuttings were measured after 50 days. 【Results】Rooting rate of Taifu cuttings under $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA treatment (85.3%) was significantly higher than those under 1000, 4000, 5000 $\text{mg} \cdot \text{L}^{-1}$ IBA+NAA treatments and that of the control. There was no prominent change in the root number with different IBA+NAA treatments, while they were all significantly higher than that of the water treatment. Root length in 4000 and 5000 $\text{mg} \cdot \text{L}^{-1}$ IBA+NAA treatments were significantly less than in other treatments. Rooting rate of Taifu cuttings under 0.4% citric acid solution treatment (89.0%) was markedly higher than those under 0.1%, 0.2%, 0.3%, 0.5% citric acid solution treatments and that of the control. Rooting number under 0.3%, 0.4%, 0.5% citric acid solution treatments were significantly larger than that under other treatments. Root length under the 0.5% citric acid solution treatment was the highest among the six treatments. The different persimmon rootstock types (Taifu and L938) had no significant difference in the rooting rate of cuttings under both $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA and 0.4% citric acid solution treatments, indicating that both of these two rootstock types could produce high rooting rate as long as the treatment condition was suitable, although the rooting number of L938 were slightly higher than those of Taifu under both treatments. The upper side and middle part of L938 cuttings were used as materials to test the effect of different vegetational parts on the rooting of the softwood cutting. The results showed that the difference of rooting rates between the upper and middle part of L938 cuttings was indistinctive under both 0.4% citric acid solution and $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA treatments, although the root number of middle part was slightly more than that of the upper side. For L938 cuttings, the rooting rates in May were significantly higher than those in July under both 0.4% citric acid solution (80.0% in May and 44.7% in July) and $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA (77.3% in May and 14.3% in July) treatments; the average rooting number (9.69) of cuttings under $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA treatment in July was distinctly higher than that of the other treatments; the average root length (5.77 cm) of cuttings under 0.4% citric acid solution treatment in July was significantly longer than that under the other treatment. For Taifu cuttings, the rooting rates in May also significantly higher than those in July under both 0.4% citric acid solution (89.0% in May and 35.7% in July) and $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA (85.0% in May and 9.7% in July) treatments, which was similar with L938 cuttings; the average rooting number (5.19) of cuttings under $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA treatment in May was clearly higher than that of the other treatments; the average root length (7.7 cm) of cuttings under 0.4% citric acid solution treatment in July was significantly longer than that under the other treatment. 【Conclusion】The propagation of persimmon rootstocks by softwood cuttings could be effectively performed in May. Both 0.4% citric acid solution and $3000 \text{ mg} \cdot \text{L}^{-1}$ IBA+NAA treatments on softwood cuttings could promote rooting, meanwhile citric acid solution treatment could enhance the occurrence of lateral roots.

Key words: Persimmon rootstock; Softwood cutting; Growth regulator; Citric acid; Rooting rate

柿(*Diospyros kaki* Thunb.)是我国重要的果树树种之一,种质资源丰富,分布区域广泛,栽培历史悠久。我国是全球柿树栽培面积最大和年产量最多的国家^[1],主产省份广西、河北、河南、山东、陕西、山

西、福建及江苏等的柿果总产量占全国总产量的75%左右^[2]。根据果实成熟时是否在树上自然脱涩可将柿品种分为甜柿和涩柿2类,我国目前的栽培品种以涩柿为主^[3]。涩柿果实需经人工或自然脱涩

处理才能食用,花费人力、物力和财力,且脱涩后的果实耐贮性降低;脱涩不完全的柿果不仅商品价值低,还导致消费者对其诱发“柿结石”的恐惧。随着消费群体和习惯的改变,涩柿生产效益持续下滑,出现卖难现象,严重制约产业的健康发展和柿农致富,给生态环境改善也造成了一定影响。甜柿果实成熟后能在树上自然脱涩而无需任何人工处理即可脆食,改善了柿果的鲜食体验,且方便贮运,是当前及未来世界柿产业重点发展的品种类型。

我国目前栽培的甜柿品种大多从日本引进,而部分品质优异的甜柿品种与我国常用的砧木君迁子出现嫁接不亲和现象^[4]。近年来,我国柿学研究者选育出部分广亲和砧木,如小果甜柿和牛眼柿^[5]等,但多适宜南方气候,抗寒性差,在我国北方地区越冬困难。L938(国家柿种质资源圃)和泰富(山东省果树研究所)分别为从君迁子和本砧中选育出的广亲和砧木,多年实践表明,它们与富有及太秋等甜柿品种的亲和性好,耐寒性较强,较适宜作为我国北方地区的甜柿砧木。但L938为雄株不能产生种子,泰富为实生繁殖的砧木,后代的亲和性有可能会发生变异,给它们的品种化及规模化应用带来很大困难,因此进行柿优良砧木的无性繁育显得十分重要。

扦插繁殖是果树苗木无性繁殖的主要方法之一^[6-7],可获得与母本遗传性一致的苗木,材料来源广、育苗周期短、管理简便、苗木质量好,便于大量育苗。笔者在本研究中以柿广亲和砧木L938君迁子和泰富(本砧)为试材,采用田间苗床全光照弥雾嫩枝扦插方法,比较L938君迁子和泰富(本砧)在不同时期和不同药剂处理下的生根状况,以期研究柿砧木嫩枝扦插的适宜条件,为柿优良砧木的品种化及规模化应用提供技术支撑。

1 材料和方法

1.1 材料

试验于2019—2020年在河北农业大学进行,试验材料为研究基地定植的柿广亲和砧木L938君迁子(国家柿种质资源圃)和泰富(本砧,山东省果树研究所)。

1.2 方法

1.2.1 不同质量浓度的药剂处理对柿砧木嫩枝扦插生根的影响 以泰富为试材,当砧木新梢长至30 cm左右时,剪取新梢、分成插段,其中顶部段为顶部3

节、保留2~3片幼叶、去除最下部一片叶;第4~5节为上部段、第6~7节为中部段、第8~9节为下部段,保留上叶的1/4~1/2、去掉下叶片,将各插段混合均匀后作为插穗。

以质量浓度为1000、2000、3000、4000、5000 mg·L⁻¹的IBA+NAA(1:1等量混合)溶液速蘸插条基部40~50 s,以0.1%(φ ,后同)、0.2%、0.3%、0.4%和0.5%的柠檬酸溶液浸泡插条基部2 h,以清水浸泡插条基部2 h为对照。扦插基质为粒度3~5 mm的纯蛭石,容器为5.0 cm×2.0 cm×8.5 cm的穴盘;穴盘填充满蛭石后,喷洒1遍1000倍的多菌灵溶液杀菌消毒。将处理好的插条2/3左右插入穴盘,共9个处理,每处理30个插条(其中顶段5~10段),随机区组,3次重复,50 d后统计生根数、根长和生根率。

1.2.2 不同药剂种类对柿砧木嫩枝扦插生根的影响 在以上试验的基础上,仍以泰富为试材,剪取新梢中上部,分成插段,每段为2节、保留上节叶的1/4~1/2、去掉下节叶片,分别以3000 mg·L⁻¹IBA+NAA(速蘸)和0.4%柠檬酸(浸泡基部)进行处理,以清水浸泡插穗基部为对照,扦插在蛭石中。共3个处理,每处理50个插条,随机区组,3次重复。50 d后调查生根率和根系状况,比较不同药剂处理对柿砧木嫩枝扦插生根的影响。

1.2.3 不同砧木类型对柿砧木嫩枝扦插生根的影响 以L938和泰富的新梢中上部为插穗(插穗处理同1.2.2),分别以3000 mg·L⁻¹IBA+NAA和0.4%柠檬酸进行处理,以清水处理为对照,扦插在蛭石中。共3个处理,每处理50个插条,随机区组,3次重复。50 d后调查生根率和根系状况,比较不同砧木类型对柿砧木嫩枝扦插生根的影响。

1.2.4 新梢不同部位对柿砧木嫩枝扦插生根的影响 以L938为试材,剪取新梢、分成插段(插穗处理同1.2.1),分别以3000 mg·L⁻¹的IBA+NAA和0.4%柠檬酸进行处理,清水处理为对照,扦插在蛭石中。共3个处理,每处理30个插条,随机区组,3次重复。50 d后调查生根率和根系状况,比较不同部位的插穗对柿砧木嫩枝扦插生根的影响。

1.2.5 不同时期柿砧木嫩枝扦插的生根状况 以L938和泰富为试材,剪取新梢中上部作插穗,分别以3000 mg·L⁻¹的IBA+NAA和0.4%柠檬酸进行处理,清水处理为对照,分别于5月中旬和7月中旬扦插,共6个处理,每处理50个插穗,随机区组,3次重

复,比较不同时期对柿砧木嫩枝扦插生根的影响。

1.3 χ^2 测验介绍

χ^2 测验这一数学方法,就是为了判定质量性状的数量资料的某种假设的理论次数与实际次数出现间的差异是由于偶然的现象还是必然的结果而提出来的。因此,应用 χ^2 测验必须有明确的假设。然后用实际发生的现象与假设比较,借以确定假设的意义。

$$\chi^2 = \sum_1^P \frac{(O-C)^2}{C}$$

χ^2 代表各类现象实际观察次数与理论次数的差异的平方与其理论次数的比值的总和,所以表示的是总的差异的程度;O代表实际观察所得的次数,即实际观察次数;C代表根据假设的理论出现次数,即理论次数或期望次数; Σ 代表总和;P代表分组数。

2 结果与分析

2.1 不同药剂及药剂质量浓度对柿砧木嫩枝扦插生根的影响

试验结果表明,不同的药剂和质量浓度处理对柿砧木的嫩枝扦插生根情况具有明显影响(表1)。当以IBA+NAA混合处理插穗时,以3000 mg·L⁻¹和2000 mg·L⁻¹的质量浓度处理,插穗的生根率最高,生根状况见图1,分别为85.3%和81.0%,显著高于其他处理,以清水处理(CK)最低,但仍有24.3%的插穗生根;各个处理质量浓度中每个插穗的平均生根条数无显著差异,但均显著多于对照;平均侧根长度以4000 mg·L⁻¹和5000 mg·L⁻¹的IBA+NAA处理最小,显著小于其他处理。



A. CK; B. 1000 mg·L⁻¹; C. 2000 mg·L⁻¹; D. 3000 mg·L⁻¹; E. 4000 mg·L⁻¹; F. 5000 mg·L⁻¹.

表1 不同质量浓度IBA+NAA处理对柿砧木嫩枝扦插生根的影响

Table 1 The effects of different concentrations of IBA+NAA on rooting of softwood cuttings of persimmon rootstock

ρ (IBA+NAA) Concentration of IBA+NAA/(mg·L ⁻¹)	生根率 Rooting rate/%	平均根数 Average number of roots	平均根长 Average number of roots/cm
1000	76.0 b	5.05 a	5.26 a
2000	81.0 ab	6.56 a	4.91 a
3000	85.3 a	5.19 a	5.19 a
4000	61.0 b	6.26 a	4.23 b
5000	57.0 b	6.12 a	4.05 b
CK	24.3 c	3.14 b	5.03 a

注:各列不同小写字母表示在 $p < 0.05$ 水平上有显著性差异。下同。

Note: Different small letters in each column of the table indicate significant differences at the $p < 0.05$. The same below.

由表2可以发现,不同体积分数的柠檬酸浸泡插穗基部处理中以0.4%生根率最高(89.0%),生根状况见图2,显著高于其他处理;其次为0.3%和0.5%处理,而以CK生根率最低,显著低于柠檬酸处

表2 不同体积分数柠檬酸处理对柿砧木嫩枝扦插生根的影响

Table 2 The effects of different concentrations of citric acid on rooting of softwood cuttings of persimmon rootstock

φ (柠檬酸) Concentration of citric acid/%	生根率 Rooting rate/%	平均根数 Average number of roots	平均根长 Average number of roots/cm
0.1	57.7 c	1.72 b	6.46 b
0.2	62.7 c	2.06 b	4.81 c
0.3	74.7 b	2.78 a	6.00 b
0.4	89.0 a	2.79 a	6.24 b
0.5	74.3 b	2.76 a	8.00 a
CK	24.3 d	2.00 b	6.53 b

Fig. 1 Rooting status of persimmon under different concentrations of IBA+NAA



A. CK; B. 0.1%; C. 0.2%; D. 0.3%; E. 0.4%; F. 0.5%.

图2 不同体积分数柠檬酸处理下柿砧木生根状况

Fig. 2 Rooting status of persimmon under different concentrations of citric acid

理;插穗的平均生根数以0.3%、0.4%和0.5%处理最多,显著多于其他处理;平均根长以0.5%最长,显著高于其他处理,以0.2%处理最小,但仍有4.81 cm。

表3结果表明,不同药剂处理对柿砧木嫩枝扦插的影响不同,柠檬酸与IBA+NAA混合处理的插穗生根率无明显差异,均显著高于CK。每个插穗的平均生根条数以IBA+NAA混合处理最多,显著高于其他处理,柠檬酸浸泡插穗基部处理生根率次之,以CK最低。平均根长以柠檬酸浸泡插穗基部处理最长,显著性高于其他处理,IBA+NAA混合处理次之,CK最小,但两者差异不显著。

表3 不同药剂处理对柿砧木嫩枝扦插生根的影响

Table 3 The effects of different chemical treatments on rooting of softwood cuttings of persimmon rootstock

处理 Treatment	生根率 Rooting rate/%	平均根数 Average number of roots	平均根长 Average number of roots/cm
0.4%柠檬酸 0.4% citric acid	89.0 a	2.79 b	6.24 a
3000 mg·L ⁻¹ IBA+NAA	85.3 a	5.19 a	5.19 b
CK	24.3 b	2.65b	5.03 b

2.2 不同砧木类型对柿砧木嫩枝扦插生根的影响

研究发现,用不同药剂的适宜质量浓度处理,2种柿砧木的嫩枝扦插生根率均无显著差异,说明君迁子和本砧2种砧木,只要处理药剂适当、处理质量浓度适宜、扦插条件合适,其嫩枝插穗都能产生较高的生根率(表4),但君迁子比本砧每插穗发生的根数稍多。

2.3 新梢不同部位插穗对柿砧木嫩枝扦插生根的影响

表5结果表明,分别以君迁子(L938)的新梢上部和中部为试材,用0.4%柠檬酸和3000 mg·L⁻¹IBA+

表4 不同砧木类型对柿砧木嫩枝扦插生根的影响

Table 4 The effects of different rootstock types on rooting of softwood cuttings of persimmon rootstock

处理 Treatment	砧木 Rootstock	生根率 χ^2 值 Rooting rate χ^2	平均根数 Average number of roots
0.4%柠檬酸 citric acid	L938 泰富 Taifu	0.7 2.7	3.2 2.7
3000 mg·L ⁻¹ IBA+NAA	L938 泰富 Taifu	2.7 5.2	6.4 5.2

注: $\chi^2_{0.05}=3.84$ 。下同。

Note: $\chi^2_{0.05}=3.84$. The same below.

NAA处理,其新梢不同部位的扦插生根率没有明显差异($\chi^2 < 3.84$),但新梢中部的平均生根数比新梢上部稍多。

表5 新梢不同部位对柿砧木嫩枝扦插生根的影响

Table 5 The effects of different parts of new shoots on rooting of softwood cuttings of persimmon rootstock

处理 Treatment	部位 Section	生根率 χ^2 值 Rooting rate χ^2	平均根数 Average number of roots
0.4%柠檬酸 0.4% citric acid	新梢上部 Upper part of new shoots	0.4	6.1
	新梢中部 New shoot middle		7.8
3000 mg·L ⁻¹ IBA+NAA	新梢上部 Upper part of new shoots	0.2	3.4
	新梢中部 New shoot middle		3.9

2.4 扦插时期对柿砧木嫩枝扦插生根的影响

试验结果表明,不同扦插时期对柿砧木的嫩枝扦插生根情况具有明显影响(表6、表7)。以L938为试材(表6),5月中旬插穗的生根率均显著高于7月中旬;就每个插穗的平均生根条数而言,以7月中

表6 不同时期扦插对君迁子L938砧木嫩枝扦插生根的影响

Table 6 The effects of cuttings in different periods on rooting of softwood cuttings of persimmon rootstock L938

时期 Time	处理 Treatment	生根率 Rooting rate/%	平均根数 Average number of roots	平均根长 Average length of roots/cm
5月中旬 Mid. May	0.4%柠檬酸 0.4% citric acid	80.0 a	3.18 c	1.13 c
	3000 mg·L ⁻¹ IBA+NAA CK	77.3 a 36.7 b	6.43 b 2.40 cd	3.81 b 1.19 c
7月中旬 Mid. July	0.4%柠檬酸 0.4% citric acid	44.7 b	2.72 cd	5.77 a
	3000 mg·L ⁻¹ IBA+NAA CK	14.3 c 12.0 c	9.69 a 1.45 d	3.03 b 3.25 b

旬3000 mg·L⁻¹IBA+NAA速蘸处理插穗的生根条数最多,显著高于其他处理,其他处理无显著差异;就平均侧根长度而言,以7月中旬0.4%柠檬酸处理最大,显著高于其他处理,以5月中旬对照处理和5月中旬0.4%柠檬酸处理最小,显著低于其他处理。以泰富为试材(表7),5月中旬插穗的生根率同样显著高于7月中旬;就每个插穗的平均生根条数而言,以5月中旬3000 mg·L⁻¹IBA+NAA速蘸处理,插穗的生根条数最多,显著高于其他处理,其他各个处理无显著差异,但5月中旬平均生根条数均多于7月中旬;就平均侧根长度而言,以7月中旬0.4%柠檬酸处理最大,显著高于其他处理,以7月中旬对照处理最小,显著低于其他处理。

表7 不同时期扦插对泰富砧木嫩枝扦插生根的影响

Table 7 The effects of cuttings in different periods on rooting of softwood cuttings of persimmon rootstock Taifu

时期 Time	处理 Treatment	生根率 Rooting rate/%	平均根数 Average number of roots	平均根长 Average length of roots/cm
5月中旬 Mid. May	0.4%柠檬酸 0.4% citric acid	89.0 a	2.65 b	6.24 ab
	3000 mg·L ⁻¹ IBA+NAA CK	85.0 a 24.3 c	5.19 a 3.14 b	5.19 bc 5.03 bc
7月中旬 Mid. July	0.4%柠檬酸 0.4% citric acid	35.7 b	2.07 b	7.70 a
	3000 mg·L ⁻¹ IBA+NAA CK	9.7 d 4.0 d	3.33 b 1.50 b	4.35 bc 4.07 c

3 讨 论

植物扦插繁殖是重要的无性繁殖方法之一,衡量扦插育苗成功与否的最重要的指标就是生根率的高低和生根质量的优劣。扦插苗成活的关键是不定根的形成,植物激素是调控扦插苗形成不定根的主要因子^[8-9]。生长素种类和浓度对扦插生根及扦插育苗效果的影响最大^[10-11],如吲哚丁酸(IBA)和萘乙酸(NAA),外源IBA的施用可以刺激根原基生长点细胞产生IAA,进一步形成根原基,促进插条生根^[12],同时,不定根原基分生组织在形成过程中,前阶段与生长素积累有关,而后阶段与低浓度的IAA有关^[13]。近年来,在揭示植物激素调节根发育研究方面有很大进展^[14-15],薛明超等^[16]以豆梨嫩枝为试材进行研究,结果表明,生长调节剂处理以1500 mg·L⁻¹IBA或1000 mg·L⁻¹NAA为好。王红宁等^[17]以樱桃矮化砧木YT101为试材的研究结果表明,IBA为1000 mg·L⁻¹处理效果最佳;张娟^[18]在对欧李嫩枝扦插生根繁殖机制的研究中发现,IAA的最佳质量浓度为3000 mg·L⁻¹,IBA为1000 mg·L⁻¹,ABT为3000 mg·L⁻¹,NAA为1000 mg·L⁻¹,国光生根粉则为3000 mg·L⁻¹。许多学者在对果树进行嫩枝扦插时大多使用单一的植物生长调节剂,如IAA、IBA、NAA或其他,使用药剂的浓度也相对较低,但对于核桃等难生根树种,需要提高植物生长调节剂的浓度,吕保聚等^[19]在探索总结核桃属植物嫩枝扦插繁殖技术时发现,以5000 mg·L⁻¹IBA+NAA(5:1)混配液速蘸处理核桃嫩枝效果为佳;刘昊^[20]在对核桃嫩枝扦插生根进行研究时同样将IBA溶液质量浓度提高到了5000 mg·L⁻¹(速蘸插穗基部)。大量试验表明,生长素是促进不定根发生的主要因素^[21-23],IBA诱导木本植物的生根效果优于IAA,原因是IBA稳定性强^[24]。外源生长素的诱导可以调节内源激素的水平,间接影响不定根的形成及根系的形成和发育^[25-26];而内源激素水平则直接与插穗生根能力密切相关^[27],同时内外激素的相互作用也是植物不定根发生的关键^[28]。黄雯^[29]以枣嫩枝插穗为试材,采用不同的外源激素处理插穗,结果表明,以IBA+NAA(1:1)处理生根效果最好、IBA次之、NAA效果较差。夏兴宏等^[30]以2 a生麻栎半木质化枝条为试材进行研究,结果表明,单用IBA处理生根数较多,但根短;单用NAA处理,尽管平均生根长度较长,但平

均生根数较少。马仕君等^[31]利用生根激素和磁场研究楸树嫩枝扦插生根的结果表明,500 mg·L⁻¹IBA+1000 mg·L⁻¹NAA处理在有磁场的情况下,不定根数量、根系生物量、平均根长、根系总长度、根系总表面积、根系总体积最大。许多研究认为生长素的相互作用在生根诱导和分化中最有效,最有效的方法是将不同的生长调节剂混合^[32]。一般认为柿为难生根树种,且预试验结果发现,单一激素IBA各质量浓度(1000~5000 mg·L⁻¹)处理生根效果均较差,因此,综合考虑前人试验结果,本试验采用IBA+NAA复配溶液速蘸处理插穗,研究发现,3000 mg·L⁻¹IBA+NAA速蘸处理,插穗的生根率最高,生根率高达85.3%,与前人研究结果基本一致。

此外,山东省果树研究所发现,柠檬酸处理对柿砧木扦插生根有促进作用(结果未发表),本研究经过2 a的多次试验发现,柠檬酸对柿砧木嫩枝扦插生根效果非常显著,不同体积分数的柠檬酸浸泡插穗基部处理中以0.4%生根率最高(89.0%)。当使用不同药剂对柿砧木的嫩枝进行处理时,柠檬酸和IBA+NAA混合处理的生根率差异不显著,每个插穗的平均生根条数以IBA+NAA混合处理最多,平均根长以柠檬酸浸泡插穗基部处理最长,并且经柠檬酸处理的插穗生根后每条根会产生许多分根,可能更利于移栽成苗。分析其可能原因,一是柠檬酸能够降低环境的pH值,使氢离子在细胞内不断累积,从而改变细胞内的渗透压,抑制细菌的生长和繁殖,防止嫩枝插穗的腐烂和褐化;二是柠檬酸可能引起插穗中的内源激素及碳水化合物含量等的变化(结果待发表)。柠檬酸促进植物生根是一个极其复杂的过程,对其促进生根的机制还需进一步深入研究。

品种、插穗的状况、扦插时期等均会影响植物扦插形成不定根。刘夏^[33]在对欧李嫩枝扦插育苗技术研究中发现,最佳采条时间为5月下旬—6月上旬。本试验研究表明,5月中旬扦插,枝条的生根率均显著高于7月中旬,与前者最佳扦插时间基本一致,原因可能是随着时间的推移,气温会越来越高,导致插穗水分含量不足,扦插成活率降低。但张伟^[34]以软枣猕猴桃为插条进行研究,结果表明7月10日扦插生根率和成苗率最高,分别达到76.7%和69.0%;张猛等^[35]以费约果嫩枝为插条进行研究,结果表明,6月20日扦插效果最佳,这与本研究结果有所差异,可能是研究地点、温度状况及试验材料和生长状况

不同所致。本研究中5月中旬扦插生根效果明显优于7月中旬扦插,一是当地5月中旬气候条件适宜,柿砧木生长旺盛,插穗的木质化程度合适,故生根率较高;7月中旬时,试验材料木质化程度很高,因此生根困难。与同材料的硬枝扦插极难生根研究结果相一致,也与黄雯^[29]对枣的研究结果相似。另外本研究所筛选的适宜扦插条件,君迁子L938与本砧泰富的试验结果无明显差异,但是是否对柿所有砧木类型通用,尚需进一步研究。

4 结 论

5月中旬扦插更利于柿砧木扦插生根,3000 mg·L⁻¹IBA+NAA速蘸及0.4%柠檬酸浸泡插穗基部,均能获得77%以上的扦插生根率,柠檬酸处理小侧根更多,君迁子(L938)和本砧(泰富)的扦插生根率差异不明显。

参考文献 References:

- [1] 罗正荣,张青林,郭大勇,徐莉清.从生物学特点和产业趋势看柿产业技术的革新[J].落叶果树,2021,53(1):4-8.
LUO Zhengrong, ZHANG Qinglin, GUO Dayong, XU Liqing. Perspectives on innovation of production technologies of persimmon based on biological characteristics and industry trends[J]. Deciduous Fruits, 2021, 53(1):4-8.
- [2] 杨勇,阮小凤,王仁梓,李高潮.柿种质资源及育种研究进展[J].西北林学院学报,2005,20(2):133-137.
YANG Yong, RUAN Xiaofeng, WANG Renzi, LI Gaochao. Advances in research of germplasm resources and breeding of *Diospyros kaki* L.[J]. Journal of Northwest Forestry University, 2005, 20(2):133-137.
- [3] TAKASHI A, AYAKO K I, KEIZO Y. Proanthocyanidin biosynthesis of persimmon (*Diospyros kaki* Thunb.) fruit[J]. Scientia Horticulturae, 2011, 130(2):373-380.
- [4] 冷平,王海龙,袁文.柿栽培北限地区引种甜柿存在问题研究[J].中国农业大学学报,2003,8(1):55-58.
LENG Ping, WANG Hailong, YUAN Wen. Problems on introducing fine sweet persimmon varieties in northern persimmon-planted area, China[J]. Journal of China Agricultural University, 2003, 8(1):55-58.
- [5] 胡梦珏,陈莉,刘一凤,张青林,罗正荣.小果甜柿和牛眼柿作为完全甜柿砧木的应用潜力研究[J].果树学报,2017,34(1):50-58.
HU Mengyu, CHEN Li, LIU Yifeng, ZHANG Qinglin, LUO Zhengrong. Potential of Xiaoguo Tianshi and Niuyanshi (*Diospyros kaki* Thunb.) as novel rootstocks for PCNA persimmon[J]. Journal of Fruit Science, 2017, 34(1):50-58.
- [6] 温四民,张桂玲,戚家栋,王良.不同磁化水处理对13种园林

- 植物硬枝扦插生根的影响[J]. 东北农业科学, 2020, 45(1):39-44.
- WEN Simin, ZHANG Guiling, QI Jiadong, WANG Liang. Effects of different magnetic water treatments on rooting of hard-wood cutting of 13 landscape plant species[J]. Journal of Northeast Agricultural Sciences, 2020, 45(1):39-44.
- [7] 耿文娟, 颜刚刚, 欧阳丽婷, 经建永, 马百强. 不同基质和激素对野生欧洲李绿枝扦插繁殖的影响[J]. 东北农业科学, 2021, 46(2):76-81.
- GENG Wenjuan, XIE Ganggang, OUYANG Liting, JING Jianyong, MA Baiqiang. Effects of different substrates and hormones on green branches cutting propagation of *Prunus domestica*[J]. Journal of Northeast Agricultural Sciences, 2021, 46(2): 76-81.
- [8] REN H Y, HU H Y, LUO X J, ZHANG C C, I X Y, LI P Y, LI W J, KHAWAR A, SUN X X, REN Z L, SHEN C J. Dynamic changes of phytohormone signaling in the base of *Taxus media* stem cuttings during adventitious root formation[J]. Scientia Horticulturae, 2019, 246(27):338-346.
- [9] NEGISHI N, NAKAHAMA K, URATA N, KOJIMA M, SAKAKIBARA H, KAWAOKA A. Hormone level analysis on adventitious root formation in *Eucalyptus globulus*[J]. New Forests, 2014, 45(4):577-587.
- [10] KESARI V, KRISHNAMACHARI A, RANGAN L. Effect of auxins on adventitious rooting from stem cuttings of candidate plus tree *Pongamia pinnata* (L.), a potential biodiesel plant[J]. Trees (Berlin), 2009, 23(3):597-604.
- [11] 吕英忠, 代永欣, 张鹏云, 史静儒, 王林. 生长调节剂对葡萄扦插苗水分代谢和碳平衡的影响[J]. 果树学报, 2020, 37(4): 511-519.
- LÜ Yingzhong, DAI Yongxin, ZHANG Pengyun, SHI Jingru, WANG Lin. Effect of plant growth regulators on water transport and carbon balance in seedling establishment of grape cuttings [J]. Journal of Fruit Science, 2020, 37(4):511-519.
- [12] 白晓燕, 王力荣, 王新卫, 朱更瑞, 方伟超, 曹珂, 陈昌文, 李勇. 桃砧木组织培养和扦插生根的解剖学观察[J]. 果树学报, 2015, 32(1):74-78.
- BAI Xiaoyan, WANG Lirong, WANG Xinwei, ZHU Gengrui, FANG Weichao, CAO Ke, CHEN Changwen, LI Yong. Microscopic observation on adventitious root development of micropropagation and cutting propagation on peach rootstocks[J]. Journal of Fruit Science, 2015, 32(1): 74-78.
- [13] 范伟国, 杨洪强. 果树根构型及其与营养和激素的关系[J]. 果树学报, 2006, 23(4):587-592.
- FAN Weiguo, YANG Hongqiang. Root system architecture and the relations to nutritional status and plant growth hormone in fruit trees[J]. Journal of Fruit Science, 2006, 23(4):587-592.
- [14] ACHARD P, VRIEZEN W H, VAN D S D, HANBERD N P. Ethylene regulates *Arabidopsis* development via the modulation of DELLA protein growth repressor function[J]. Plant Cell Reports, 2003, 15(12):2816-2825.
- [15] FU X, HARBERD N P. Auxin promotes *Arabidopsis* root growth by modulating gibberellin response[J]. Nature, 2003, 421(6924):740-743.
- [16] 薛明超, 马春晖, 李鼎立, 姚锐, 张欢, 宋奎波, 王然. 不同梨砧木嫩枝扦插繁殖技术研究[J]. 中国果树, 2015(3):35-38.
- XUE Mingchao, MA Chunhui, LI Dingli, YAO Kun, ZHANG Huan, SONG Kuibo, WANG Ran. Research on tender cutting propagation techniques of different pear rootstocks[J]. China Fruits, 2015 (3):35-38.
- [17] 王红宁, 孙俊宝, 张生智, 尹蓉, 刘宏太, 孙慧英. 植物生长调节剂对樱桃矮化砧木‘YT101’嫩枝扦插生根的影响[J]. 农学学报, 2019, 9(7):44-47.
- WANG Hongning, SUN Junbao, ZHANG Shengzhi, YIN Rong, LIU Hongtai, SUN Huiying. Effects of plant growth regulators on cutting rooting of twigs of cherry dwarf-rootstock ‘YT101’ [J]. Journal of Agriculture, 2019, 9(7):44-47.
- [18] 张娟. 欧李嫩枝扦插生根繁殖机理的研究[D]. 晋中: 山西农业大学, 2005.
- ZHANG Juan. Research on the soft-wood cutting propagation for Chinese dwarf cherry (*Cerasus humilis* Bge.)[D]. Jinzhong: Shanxi Agricultural University, 2005.
- [19] 吕保聚, 裴东, 徐虎智, 郭志敏, 马彩霞. 核桃属植物嫩枝扦插生根的影响因素分析[J]. 安徽农业科学, 2008, 36(29):12659-12660.
- LÜ Baoju, PEI Dong, XU Huzhi, GUO Zhimin, MA Caixia. Analysis of influencing factors of cutting rootage of *Juglans regia* Linn. tender branches[J]. Journal of Anhui Agricultural Sciences, 2008, 36(29):12659-12660.
- [20] 刘昊. 核桃复幼促进扦插生根的多激素作用机制[D]. 北京: 中国林业科学研究院, 2017.
- LIU Hao. The mechanism of multiple hormonal on promoting rooting during cutting of walnut rejuvenation[D]. Beijing: Chinese Academy of Forestry, 2017.
- [21] SAINI S, SHARMA I, KAUR N, PATI P K. Auxin: A master regulator in plant root development[J]. Plant Cell Reports, 2013, 32(6):741-757.
- [22] PACURAR D I, PERRONE I, BELLINI C. Auxin is a central player in the hormone cross-talks that control adventitious rooting[J]. Physiologia Plantarum, 2014, 151(1):83-96.
- [23] ALMEIDA M R, BASTIANI D, GAETA M L. Comparative transcriptional analysis provides new insights into the molecular basis of adventitious rooting recalcitrance in *Eucalyptus*[J]. Plant Science, 2015, 239(7): 155-165.
- [24] 张乐华, 王书胜, 单文, 李晓花, 王凯红, 王兆宏. 基质、激素种类及其浓度对鹿角杜鹃扦插育苗的影响[J]. 林业科学, 2014, 50(3):45-54.
- ZHANG Lehua, WANG Shusheng, SHAN Wen, LI Xiaohua, WANG Kaihong, WANG Zhaozhong. Influences of growth media, and hormone types and concentrations on cutting propaga-

- tion of *Rhododendron latoucheae*[J]. *Scientia Silvae Sinicae*, 2014,50(3):45-54.
- [25] HENRIQUE A, CAMPINHOS E N, ONO E O. Effect of plant growth regulators in the rooting of *Pinus* cuttings[J]. *Brazilian Archives of Biology and Technology*, 2006,49(2):189-196.
- [26] OUYANG F Q, WANG J, LI Y. Effects of cutting size and exogenous hormone treatment on rooting of shoot cuttings in Norway spruce (*Picea abies* (L.) Karst.)[J]. *New Forests*, 2015, 46 (1):91-105.
- [27] NORDSTRÖM A C, ELIASSON L. Levels of endogenous indole-3-acetic acid and indole-3-acetylaspartic acid during adventitious root formation in pea cuttings[J]. *Physiologia Plantarum*, 1991,82(4):599-605.
- [28] 闫帅,张少瑜,徐锴,袁继存,李晓光,周江涛,程存刚,赵德英. 杜梨组培生根过程中多胺、内源激素及相关氧化酶活性的变化[J]. 果树学报,2019,36(3):318-326.
- YAN Shuai, ZHANG Shaoyu, XU Kai, YUAN Jicun, LI Xiaoguang, ZHOU Jiangtao, CHENG Cungang, ZHAO Deying. Dynamic changes in polyamines, endogenous hormones and oxidase activities during rooting of *in vitro* plantlets of *Pyrus betulifolia* Bunge[J]. *Journal of Fruit Science*, 2019, 36(3):318-326.
- [29] 黄雯. 不同外源激素处理对枣嫩枝扦插生根机理研究[D]. 长沙:中南林业科技大学,2015.
- HUANG Wen. Studies on cutting propagation technology and rooting mechanism of *Ziziphus jujuba* Mill. with different exogenous hormone[D]. Changsha: Central South University of Forestry and Technology, 2015.
- [30] 夏兴宏,张耀廷,王连珍,郎庆龙,李喜升,费腾,李立峰,孙娟,高伟,于艳. 不同因素对麻栎绿枝扦插生根的影响[J]. 蚕业科学,2019,45(6):915-920.
- XIA Xinghong, ZHANG Yaotong, WANG Lianzhen, LANG Qing-
- long, LI Xisheng, FEI Teng, LI Lifeng, SUN Juan, GAO Wei, YU Yan. Effects of different factors on rooting ability of *Quercus acutissima*[J]. *Science of Sericulture*, 2019, 45(6):915-920.
- [31] 马仕君,彭泰来,余韵,刘勇,李成,王洁. 生根激素和磁场对楸树嫩枝扦插生根的影响[J]. 东北林业大学学报,2020,48 (6):21-24.
- MA Shijun, PENG Tailai, YU Yun, LIU Yong, LI Cheng, WANG Jie. Effect of plant hormones and magnetic field on rooting of soft cuttings for *Catalpa bungei*[J]. *Journal of Northeast Forestry University*, 2020, 48(6): 21-24.
- [32] KESARI V, KRISHNAMACHARI A, RANGAN L. Effect of auxins on adventitious rooting from stem cuttings of candidate plus tree *Pongamia pinnata* (L.), a potential biodiesel plant[J]. *Trees (Berlin)*, 2009, 23(3):597-604.
- [33] 刘夏. 欧李嫩枝扦插育苗技术研究[D]. 秦皇岛:河北科技师范学院,2019.
- LIU Xia. Research on the soft-wood cutting propagation techniques of *Prunus humilis*[D]. Qinhuangdao: Hebei Normal University of Science and Technology, 2019.
- [34] 张伟. 扦插时期对软枣猕猴桃生根和成苗率的影响[J]. 防护林科技,2016(3):44-46.
- ZHANG Wei. The effects of cutting time on rooting and seedling rate of *Actinidia arguta*[J]. *Protection Forest*, 2016(3): 44-46.
- [35] 张猛,王丹,任少雄,刘仁道. 树龄及扦插时期和采穗部位对费约果嫩枝扦插生根的影响[J]. 北方园艺,2010(6):32-34.
- ZHANG Meng, WANG Dan, REN Shaohong, LIU Rendao. Effects of ortet age, cutting period and cutting position on cutting propagation of *Feijoa sellowiana*[J]. *Northern Horticulture*, 2010 (6):32-34.

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