



4种矮化砧木对再植苹果幼树生长、产量和品质的影响

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摘要:【目的】连续4年调查研究再植条件下4种矮化自根砧(G935、G41、G11和M9-T337)对‘官藤’富士苹果幼树树体生长、早果性和产量及品质的影响,评价并筛选适宜北京地区再植使用的苹果矮化自根砧木,为我国老龄低效苹果园再植更新提供技术支撑。【方法】2016年春,刨除6年生苹果树(官藤富士/SH6/圆叶海棠),未进行土壤改良,在原行内重茬直接栽植4种矮化自根砧(G935、G11、G41和M9-T337),品种为官藤富士苹果苗(2年根1年干),株行距为1 m×3.8 m,细纺锤整形修剪,再植后(2016年)连续4年调查4种矮化自根砧嫁接‘官藤富士’苹果树体生长、早果性和产量及品质的差异。【结果】G935和G41自根砧富士树体高度明显高于G11和M9-T337;主枝数量由高到低为:G935>G41>G11>M9-T337;G41和M9-T337大脚现象明显高于G935和G11;G935和G41单株间树体高度、干径和主枝数量差异明显小于G11和M9-T337,园相整齐。再植第4年,G935和G41自根砧树体叶片叶绿素含量和净光合速率显著高于G11和M9-T337,G935和G41叶片百叶鲜重显著高于G11和M9-T337,G935和G41叶片百叶干重显著高于M9-T337。再植4年内,G935和G41矮化自根砧富士生长正常,枝类组成符合正茬矮砧苹果的变化规律;第2年开始,G11和M9-T337树体长枝比例低于30%;第3年和第4年G11和M9-T337树体短枝比例高于80%,长枝比例低于10%,树势衰弱明显。再植第3年,G11幼树成花株率最高,G935和G41次之,M9-T337无成花。再植第4年,G935和G41自根砧富士平均单株产量显著高于M9-T337,G935平均单果重量和果形指数显著高于其他自根砧,各自根砧树体果实可溶性固形物含量、可滴定酸含量和固酸比均无显著差异。【结论】再植条件下,以G935和G41为砧木的幼树树体生长显著优于G11和M9-T337,枝类组成合理,树势中庸但不衰弱,单株间差异小,园相整齐,适宜北京地区重茬栽植使用。

关键词: 苹果再植; G系砧木; 矮化自根砧; 富士苹果; 树体生长; 果实产量; 果实品质

Effects of 4 Dwarfing Rootstocks on Growth, Yield and Fruit Quality of ‘Fuji’ Sapling in Apple Replant Orchard

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Abstract: 【Objective】 The effects of four dwarfing rootstocks (G935, G41, G11 and M9-T337) on the growth, early fruiting and yield quality of Fuji apple saplings under the replanting conditions were investigated for four years. The dwarfing rootstocks suitable for continuous cropping in Beijing were evaluated and selected, so as to provide a technical support for the renewal of the

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cultivation mode of old and inefficient apple orchards in China. 【Method】 In the spring of 2016, 6-year-old apple trees (Fuji/SH6/*Malus prunifolia*) were planed out and no soil improvement was carried out. 4 dwarfing rootstocks (G935, G11, G41 and M9-T337) Fuji apple seedlings (2-year-old roots and 1-year-dry) were directly planted in the original row, with a row spacing of 1 m×3.8 m. After planting, 4 dwarfing plants were investigated differences of tree growth, early fruiting, yield and quality of Fuji apple on rootstock for 4 consecutive years. 【Result】 The height of Fuji trees on G935 and G41 rootstock was higher than that of G11 and M9-T337; the number of main branches from high to low was: G935>G41>G11>M9-T337; the phenomenon of big feet of G41 and M9-T337 was higher than that of G935 and G11; the difference of height, diameter and number of main branches between G935 and G41 was significantly lower than that of G11 and M9-T337, with the neat garden phase. In the fourth year of continuous cropping, the chlorophyll content and net photosynthetic rate of leaves of G935 and G41 rootstocks were significantly higher than G11 and M9-T337, the fresh weight of leaves of G935 and G41 was significantly higher than G11 and M9-T337, and the dry weight of leaves of G935 and G41 was significantly higher than M9-T337. Within 4 years of continuous cropping, Fuji, the dwarfing rootstock of G935 and G41, grew normally, and the branch composition was in line with the change rule of dwarf rootstock fruit trees. From the second year, the proportion of long branches of G11 and M9-T337 trees was lower than 30%; from the third and fourth year, the proportion of short branches of G11 and M9-T337 trees was higher than 80%, the proportion of long branches was lower than 10%, and the tree vigor was obviously weakened. In the third year of continuous cropping, the flowering rate of G11 young trees was the highest, followed by G935 and G41, and M9-T337 had no flowering. In the fourth year of continuous cropping, the average yield per plant of Fuji on G935 and G41 rootstocks was significantly higher than that of M9-T337 and the average fruit weight and fruit shape index of G935 were significantly higher than those of other rootstocks. There were no significant differences in the soluble solid content, titratable acid content and solid acid ratio of the fruit of each rootstock. 【Conclusion】 Under the condition of replantation, the growth of young trees with G935 and G41 as rootstocks was significantly better than that of G11 and M9-T337. The branch composition was reasonable, the tree potential was moderate but not weak, the difference between single plants was small, and the garden was neat, which was suitable for continuous cropping in Beijing.

Key words: apple replant orchard; G dwarfing rootstocks; Fuji apple; tree growth; fruit yield; fruit quality

0 引言

【研究意义】中国是世界最大的苹果生产和消费国,栽培面积和总产量均占世界的 50%以上。近三四十年来,苹果矮砧栽培已经成为发展方向,欧美等发达国家苹果矮砧栽培比例已占 90%以上^[1-6],目前我国 90%左右的苹果园仍采用乔化栽培模式,近几年,苹果矮砧栽培再次掀起高潮,而矮化栽培的比例仍不足 10%,发展较慢,矮化中间砧或短枝型的矮化栽培模式占比较高^[6-8]。我国现有苹果园中,70%以上的果园树龄在 25 年以上,树龄老化和低效等问题严重制约了苹果产业的可持续发展。由于我国土地资源有限,苹果种植比较集中(环渤海湾和黄土高原约占 70%),老龄低效果园更新的再植障碍(重茬)问题严重制约了我国苹果由传统栽培向矮砧集约栽培模式的转换。评价、筛选、培育适宜我国再植使用的苹果矮化自根砧木,对于我国老龄低效苹果园更新和栽培模式升级具有重要意义。【前人研究进展】苹果连作障碍又称为苹果再植病,苹果树重茬建园时,新栽植的苹果幼树多表现为成活率下降、树体生长弱、单株个体差异

大、结果晚等问题^[9-13]。国内关于苹果再植障碍做了大量研究,但大都集中在重茬抑制生长机理研究和如何通过土壤处理等方法减少重茬影响方面^[14-16]。选择抗重茬砧木是解决苹果再植问题的重要途径之一,我国自 20 世纪 60 年代就开始苹果矮砧栽培研究工作,先后引进了英国东茂林试验站的 M 系、MM 系,波兰的 P 系,加拿大的 O 系,原苏联的 B 系和美国的 MAC 等苹果矮化砧木,由于砧木生态适应性及栽培技术不配套等问题,至今保留下的果园甚微^[17-22]。国外相关研究起步较早,相关机理研究已经较深入,并且已经有关于抗重茬砧木育种和应用的报道,其中美国农业部 and 康奈尔大学 Geneva 试验站对新育成的 G 系砧木进行了抗重茬能力的评价^[9,23-24]。【本研究切入点】我国土壤气候条件下再植苹果园矮化砧木的评价有待研究。【拟解决的关键问题】本研究以从国外商务购买的 4 种苹果矮化自根砧木(G935、G41、G11 和 M9-T337)嫁接‘宫藤富士’为材料,探讨再植苹果园 4 种矮化自根砧木对‘富士’苹果幼树树体生长、早果性和产量及品质的影响,为我国老龄低效苹果园更新建园提供技术支撑。

1 材料与方法

试验于 2016—2019 年在北京市顺义区杨镇苹果产业技术研发基地苹果园(北纬 39°97′, 东经 116°23′)进行。

1.1 试验材料

2016 年春季, 刨除 6 年生苹果树(宫藤富士/SH6/圆叶海棠, 株行距为 1 m×3.8 m)后, 原土壤不做任何改良, 果园土壤为壤土, 全氮 1.04 g·kg⁻¹, 碱解氮 65.2 mg·kg⁻¹, 有效磷 21.2 mg·kg⁻¹, 有效钾 113 mg·kg⁻¹, 有机质 14.4 g·kg⁻¹, pH 8.09; 在原行内开宽、深各 20 cm 左右的小沟, 按照株距 1 m 种植 4 种矮化自根砧(G935、G11、G41 和 M9-T337, 正规购买获得)嫁接‘宫藤富士’的苗木, 砧木露出地面 10—15 cm, 每种砧木栽植 120 株, 每 4 行主栽品种配置一行‘王林’为授粉树。按照细纺锤形进行整形和修剪, 水肥一体化滴灌系统进行正常肥水管理。

1.2 试验方法

自种植后, 每个处理选择 20 株为试验树, 每年落叶后用游标卡尺测量不同砧木嫁接接口上 10 cm 处品种的树干粗度和嫁接接口下 5 cm 处砧木的树干粗度, 并计算砧穗干周比, 调查树冠内不同长度的枝条类型(< 5 cm、5—15 cm、15—30 cm 和 >30 cm)的数量, 计算统计主枝数量和枝类组成; 2018 年春, 调查 4 种自根砧树体成花株数。2019 年, 试验树果实成熟后全部采收, 统计果实产量; 果实成熟时, 在每株树冠的中上部东南方向取 3 个果实, 共 60 个, 带回实验室测定果实品质, 用百分之一天平测量果实单果重; 用游标卡尺测量果实的横径、纵径, 计算统计果形指数; 用 GY-1 型果实硬度计测定果实硬度; 用 PR-100 型数字糖度计测定果实可溶性固形物含量; 用 0.1 mol·L⁻¹ NaOH 中和滴定法测定果实可滴定酸含量。

1.3 数据处理与分析

应用 PASW Statistics 18 和 Excel 等软件进行数据的计算统计和分析。

2 结果

2.1 再植条件下 4 种矮化自根砧富士树体生长的差异

2.1.1 树体高度、主枝数量和树干粗度的差异
从图 1 可以看出, 随着树龄的增长, 4 种矮化自根砧富士树体高度、树干粗度和主枝数量逐年增加, 不同砧木间存在显著差异。G935 和 G41 树体高度明显高于 G11 和 M9-T337; 主枝数量由高到低为: G935>G41>G11>M9-T337; G41 和 M9-T337“大脚”现象明显高于 G935 和 G11。从图中误差线可以看出, G935 和 G41 单株间树体高度、干径和主枝数量差异较小, 园相整齐, 而 G11 和 M9-T337 单株间树体高度、干径和主枝数量波动巨大, 园相不整齐。

2.1.2 树体枝类组成的差异
如图 2 所示, 4 种矮化自根砧‘富士’树体间的枝类组成存在较大差异。再植第 2 年至第 4 年, 各矮化自根砧树体短枝比例不断增加, 长枝比例不断减少。G935 和 G41 生长正常, 枝类组成变化符合正茬矮砧苹果的变化规律。再植第 2 年开始, G11 和 M9-T337 树体长枝比例低于 30%; 再植第 3 年和第 4 年, G11 和 M9-T337 树体短枝比例高于 80%, 长枝比例低于 10%, 树势衰弱明显。

2.1.3 叶片质量的差异
再植条件下, 4 种矮化自根砧‘富士’叶片质量存在较大差异(表 1): 再植第 4 年(2019 年), G935 和 G41 自根砧树体叶片叶绿素含量和净光合速率显著高于 G11 和 M9-T337, G935 和 G41 叶片百叶鲜重显著高于 G11 和 M9-T337, G935 和 G41 叶片百叶干重显著高于 M9-T337。

表 1 再植第 4 年 4 种矮化自根砧‘富士’苹果树体叶片质量的差异

Table 1 Differences in leaf quality of 4 dwarfing rootstocks Fuji apple trees in the 4th year of continuous cropping

砧木类型	新梢长度	叶绿素含量	净光合速率	百叶重鲜重	百叶重干重
Different rootstocks	Length of new branches	Chlorophyll content	Net Photosynthesis rate	Fresh weight of one	Dry weight of one
	(cm)	(mg·g ⁻¹)	(μmol·m ⁻² ·s ⁻¹)	hundred leaves (g)	hundred leaves (g)
G935	61.5a	64.58a	12.08a	106.28a	37.29a
G41	44.8b	65.41a	12.58a	102.63a	36.81a
G11	28.5c	58.34b	9.86b	95.47b	32.78ab
M9-T337	25.4c	57.29b	9.58b	94.25b	31.29b

多重比较采用新复极差测验, 同一列不同小写字母表示不同数据之间达到 5%显著性差异水平。下同
Statistical multiple comparison according to the Duncan's test, the different letters indicate significant difference at 0.05 level. The same as below

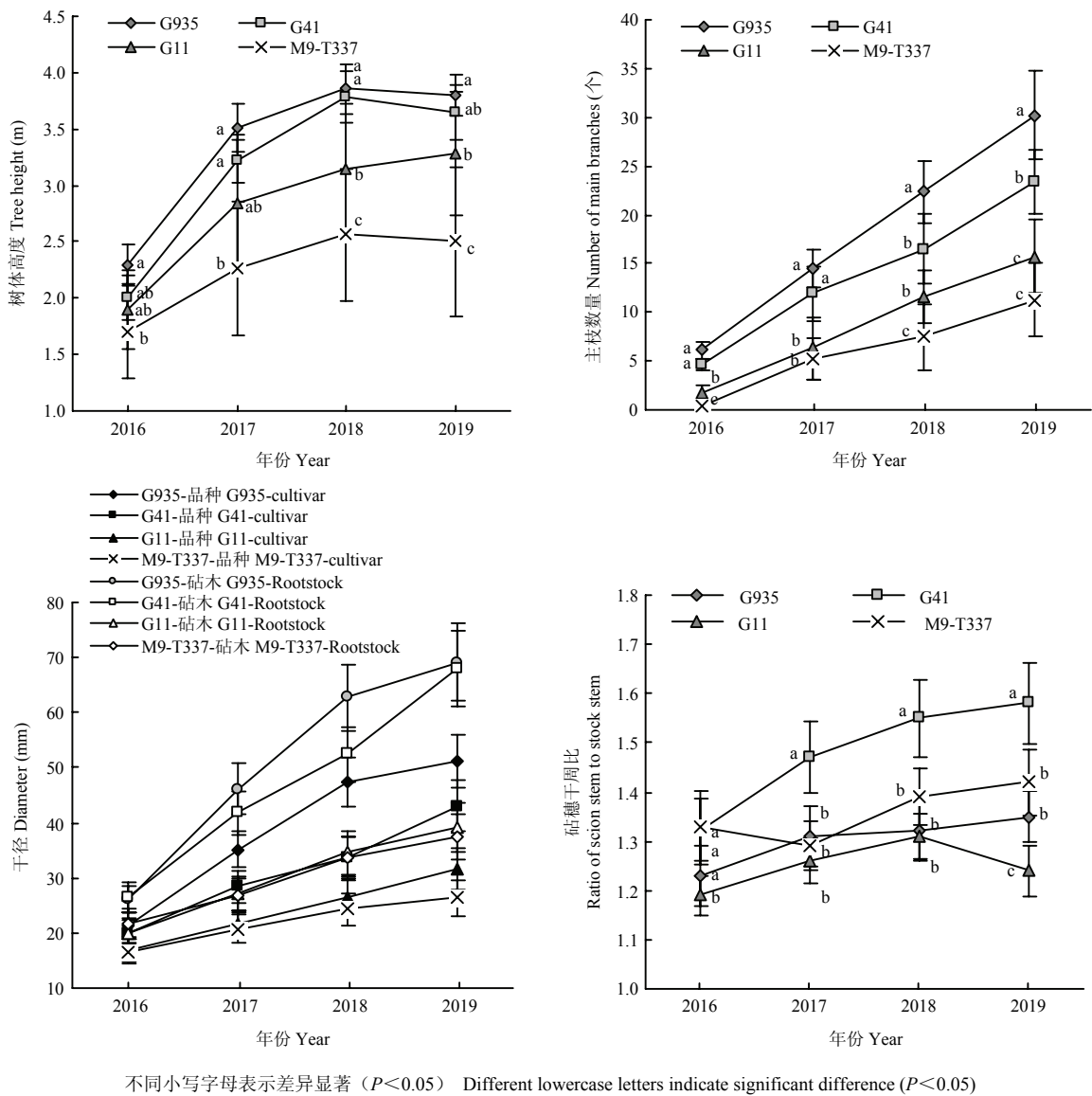


图1 再植条件下不同矮化自根砧‘富士’苹果树体高度、树干粗度和主枝数量的年变化

Fig. 1 Annual variation of height, trunk diameter and number of main branches of Fuji apple trees with different dwarfing rootstocks under repeated cropping conditions

2.2 再植条件下4种矮化自根砧‘富士’早期成花和产量品质的差异

2.2.1 早期成花的差异 2018年春调查4种矮化自根砧富士成花情况，如表2所示。G11幼树成花株率最高为34.9%，G935和G41幼树成花株率较为相近，分别为19.5%和21.9%。T337幼树部分死亡，存活的树体无成花。

2.2.2 对果实品质的影响 再植第4年（2019年）果实品质的调查结果显示，4种矮化自根砧‘富士’苹果果实产量和品质的差异显著。再植第4年，G935

表2 4种矮化自根砧‘富士’苹果树体成花的差异
Table 2 Flowering difference of 4 dwarfing rootstocks of Fuji apple trees in the 3rd year of continuous cropping

砧木类型	成花株率
Different rootstocks	Rate of flowering plants (%)
G935	19.5%b
G41	21.9%b
G11	34.9%a
T337	0c

和G41 自根砧‘富士’平均单株产量显著高于M9-T337; 且 G935 和 G41 单株间产量差异较小, 园相整齐, G11 和 M9-T337 单株间产量差异很大, 园相非常不整齐。

G935 自根砧 ‘富士’ 平均单果重量和果形指数显著高于其他自根砧。4 种自根砧 ‘富士’ 果实的可溶性固形物含量、可滴定酸含量和固酸比均无显著差异 (表 3)。

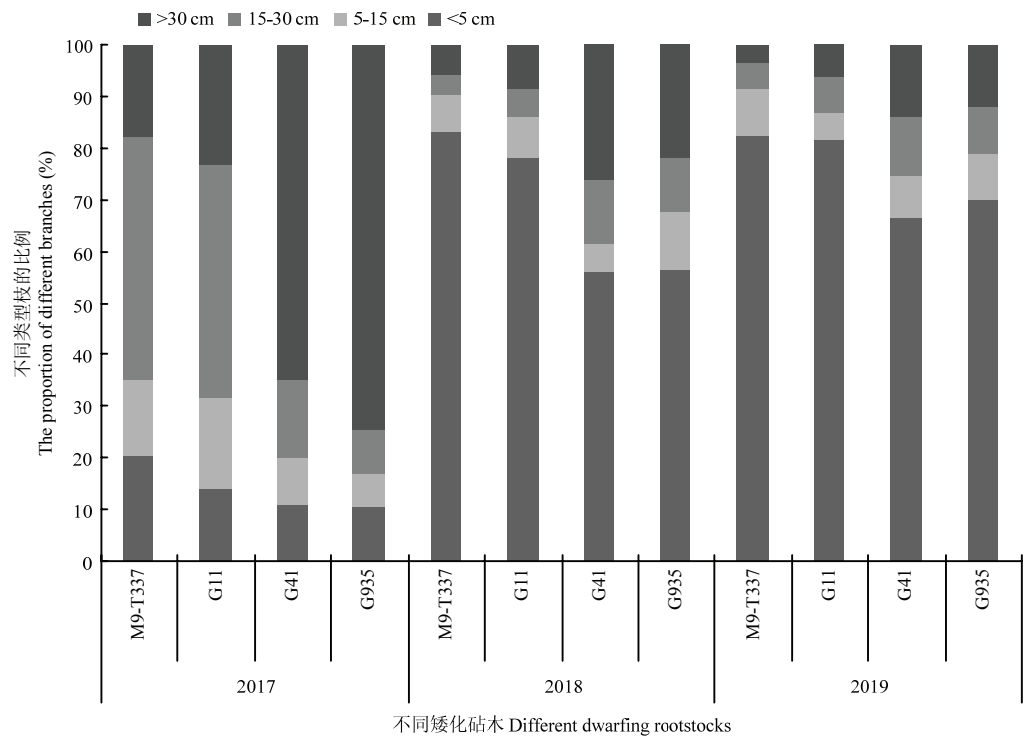


图 2 再植条件下不同矮化自根砧 ‘富士’ 苹果树体枝类组成的年变化

Fig. 2 Annual variation of branch composition in different dwarfing rootstocks of Fuji apple trees with different dwarfing rootstocks under repeated cropping conditions

表 3 4 种矮化自根砧 ‘富士’ 苹果果实产量和品质的差异 (再植第 4 年)

Table 3 Differences in fruit quality of four dwarfing rootstocks of Fuji apple in the fourth year of repeated cropping

砧木类型 Rootstock type	平均单株产量 Average yield of single plant (kg/plant)	平均单果重 Mean fruit mass (g)	果形指数 Fruit figure index	可溶性固性物料含量 Soluble solids (%)	可滴定酸含量 Titratable acidity (%)	固酸比 TSS/TA
G935	11.03±1.51a	221.1a	0.85a	16.2a	0.29a	58.29a
G41	10.48±1.22a	189.2b	0.79b	15.9a	0.28a	56.51a
G11	7.36±4.15ab	190.3b	0.79b	16.3a	0.30a	57.94a
M9-T337	4.31±1.68b	167.5c	0.77b	15.9a	0.29a	56.24a

3 讨论

M9-T337 是由荷兰木本植物苗圃检测服务中心 (NAKTUINBOUW) 选育的苹果矮化砧木, M9-T337 自根砧苹果具有矮化性强、结果早、品质高等优点^[25-26], 近十年来在我国应用较多, 但也存

在抗寒性较差、不抗重茬和肥水要求高等缺点, 难以满足目前我国大面积老龄低效果园更新和部分产区寒冷、干旱的气候特点。美国从 1968 年开始苹果砧木育种, 目前已成功选育出具有较大应用和科研价值的已申请专利的 14 个 G 系苹果砧木品种, 其中不同砧木分别具有抗火疫病、抗颈腐病、抗绵蚜、

抗重茬等优良抗性^[9,23-24]。G 系砧木中具有抗重茬能力的矮化砧木可直接应用于我国目前老果园更新, 或作为亲本培育具有自主知产权的适宜我国不同生态区的矮化砧木。

再植条件下, 4 种矮化自根砧‘宫藤富士’苹果树体生长和早期结果的差异巨大。随着树龄的增长, 4 种矮化自根砧‘富士’树体高度、树干粗度和主枝数量逐年增加, 不同砧木间存在显著差异。G935 和 G41 树体长势显著优于 G11 和 M9-T337, G11 和 M9-T337 主干生长势很弱, G41 和 M9-T337 树体出现较严重的“大脚”现象。足够的枝量是树体早果丰产的前提, 再植第 4 年, G935 和 G41 树体平均主枝数量均超过了 25 个, 分别为 30.2 和 26.4, 能够满足矮砧密植的枝量要求^[9-12,27-29]; 而 G11 和 M9-T337 主枝仅为 15.7 和 11.3, 主枝数量严重不足。园相整齐是判断砧木抗重茬能力的指标之一^[7-13], G935 和 G41 单株间树体高度、干径和主枝数量差异明显小于 G11 和 M9-T337, 园相整齐。果树的枝类组成直接影响树体的生长势和产量品质, 前人研究表明, 一般情况下矮砧苹果正茬栽植后前 3—4 年, 树体的长枝比例不断减少, 短枝比例不断增加, 到第 4、5 年树体短枝比例均达到最大值并开始趋于稳定^[30-32]。本研究中, 再植第 2—4 年, G935 和 G41 树体生长正常, 枝类组成变化符合正茬矮砧苹果枝类组成的变化规律; 而 G11 和 M9-T337 树体再植第 2 年开始, 长枝比例便低于 30%, 第 3 年和第 4 年树势衰弱明显^[33-34]。叶片质量是决定光合营养积累和产量的重要决定性因素, 再植条件下不同自根砧的叶片质量也是筛选抗重茬砧木的重要指标。

4 结论

根据再植条件下, 4 种不同矮化自根砧‘富士’幼树 4 年的树体生长、早花性和产量品质情况, 以 G935 和 G41 自根砧为砧木的‘富士’幼树树体生长显著优于 G11 和 M9-T337, 枝类组成合理, 树势中庸但不衰弱, 单株间差异小, 园相整齐, 适宜北京地区重茬栽植使用。

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