

# 新中国果树科学研究70年——樱桃

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**摘要:**新中国成立70年来樱桃研究取得了较快的发展。我国现有樱桃栽培面积约26.67万hm<sup>2</sup>, 其中甜樱桃23.33万hm<sup>2</sup>。在资源育种方面, 收集保存种质资源500余份, 自主选育甜樱桃新品种40余个, 砧木品种10余个。自主培育的品种‘红灯’占我国甜樱桃栽培总面积的40%。开发出自交亲和性与果实颜色等性状基因标记, 实际用于育种亲本选配和后代预先选择。绘制甜樱桃的分子遗传图谱, 图距0.96 cM, 并定位果实大小、糖酸比等QTLs。栽培品种DNA指纹图谱真伪与纯度鉴定工作得到商业应用。在栽培方面, 研制推广了无性系砧木绿枝前插技术, 研发出高精度无病毒苗木分子鉴定技术, 提高了苗木整齐度和苗木质量; 试验示范了高纺锤形、超细纺锤形、KGB及UFO等树形, 促进了果园标准化。设施栽培技术发展迅速, 形成了大连日光温室和临朐高架保温大棚两种栽培模式, 栽培面积达1.33万hm<sup>2</sup>。在采后方面, 研制出MA贮藏病害控制技术。由于樱桃科立项困难, 除育种领域外, 多数领域研究处于生产经验总结阶段, 严重滞后于生产发展。

**关键词:** 樱桃; 新中国; 70年; 科学研究; 回顾; 展望

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## Fruit scientific research in New China in the past 70 years: Cherry

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**Abstract:** In the past 70 years, cherry scientific research in New China has achieved rapid development. The total cherry plantation in China reached about 266 000 hm<sup>2</sup> by 2018, including the sweet cherry for about 233 000 hm<sup>2</sup> and Chinese cherry for about 33 000 hm<sup>2</sup>, with the total production of 1 700 000 tons. After decades of development, more than 500 collections of cherry germplasms are preserved. Sweet cherry breeding program started in 1960's, till now, more than 40 new cultivars are released. 'Hongdeng', bred in 1976, is the most successful cultivar, which planted up to 40% of the total sweet cherry cultivation in China. Other promising new cultivars would be 'Chunlu' 'Luying3' 'Miquan' 'Fuxing', etc. Besides, more than 10 rootstock cultivars were released, including 'Landing 2' 'Jingchun' 'Y1' etc. In molecular assisted breeding, self-fertile allele S4' could be detected by PCR makers using the 4 bp deletion in the S4' SFB, fruit color trait could be selected by screening PavMYB10.1, a key gene in the anthocyanin synthesis pathway. A genetic map using a cross between cultivars 'Wanhongzhu' and 'Lapins' is built with a distance of 0.96 cM, and QTLs such as sugar-acid ratio and fruit size are located. Five most polymorphic SSR markers, along with S-genotype, are found to be able to distinguish 95 sweet commercial cherry cultivars, furthermore, this DNA fingerprinting method has

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been commercially applied in the authenticity and purity identification of cherry cultivars. Transgenic plants were reported using rootstocks such as Gisela6, Colt, CAB-6p, Landing2, and selections from *P. pseudocerasus*. Tissue regeneration technologies limits transgenic research in *P. avium*. Compared with *in vitro* propagation, Cutting is superior in low expenses and simply facilities, and finally developed as a major rootstock propagation method for Gisela, Landing, Jingchun, and CAB etc. RT-PCR, multiplex PCR, and small RNA sequencing are used for cherry virus identification, in order to produce virus free propagation materials. More than 20 viruses are found and identified in sweet cherry so far in China, including *Prunus Necrotic Ring spot Virus*, *Prune Dwarf Virus*, *Cherry Green Ring Mottle Virus*, *Little Cherry Virus 1*, *Little Cherry Virus 2*, *Cherry Virus A*, *Cherry necrotic rusty mottle virus*, *Cherry rasp leaf virus*, *Cucumber mosaic virus*, *Plum bark necrosis stem pitting-associated virus*, *Hop stunt viroid*, *Candidatus Phytoplasmas ziziphi*, etc. Major sweet cherry plantation regions include Bohai Bay area and Longhai railway line. Bohai bay region includes Yantai, Tai'an in Shandong, Dalian in Liaoning, Beijing, and Qinhuangdao in Hebei. And along the Longhai railway line, there are Zhengzhou in Henan, Shaanxi, south Shanxi, and Tianshui in Gansu, etc. Furthermore, new plantations are expanding in the southwest high elevation areas and in the far northwest such as Xinjiang province. Chinese cherry (*P. pseudocerasus*), which is mainly used for fresh consuming and picking up tourism, is commercially planted in southern and southwest of China, such as Yangtze river basin and Sichuan, Guizhou, and Yunnan provinces, where sweet cherry cultivation is somewhat limited by climate factors. Central Leader is the most popular used training system, and very new training system such as TSA, SSA, KGB, UFO, Bi-Axis, Tri-Axis, and Trellis were under testing in different locations. Plant regulator were found useful to control vegetative grow, promoting flower differentiation, inducing parthenocarpy and improving fruit qualities. In recent years, green house plantation grows up quickly to about 13 000 hm<sup>2</sup>, and gradually typified by the following 2 types of greenhouse cultivation. Dalian Greenhouse type is constructed with a thick solid walls, at north back and both sides for storing solar energy and keeping warmness, has been effectively applied in northern areas, especially in Liaoning province. The other one, Linqu Tall-Frame-Greenhouse type, equipped with rolling quilts to keep warm, is featured with the height of about 7 m to 10 m, normally width of above 20 m, length of 60 m to 100 m, this bigger size type increases land use efficient and machinery mobility. Greenhouse cherry trees produce top quality cherries with high and stable yields in earlier season from February to May, ensuring good selling price. Post-harvest researches focused on disease control and logistic storage. CA and MA storage were investigated, and MA is found convenient and low cost for short term storage and logistic storage in sweet cherries.

**Key words:** Cherries; New China; 70 years; Scientific research; Review; Prospect

樱桃是落叶果树中最早成熟的水果,外观美丽,风味浓郁,深受国人喜爱。新中国成立70年来,我国樱桃科学研究取得了较快发展。我国现有甜樱桃栽培面积约23.33万hm<sup>2</sup>,中国樱桃约3.33万hm<sup>2</sup>,总产量约170万t。2018年进口甜樱桃18.6万t,进口额13亿美元。

## 1 樱桃种质资源研究

樱桃属于蔷薇科李属(*Prunus* L.)樱亚属(subgen. *Cerasus*),分布广泛,全世界共有150余种<sup>[1]</sup>,源

于我国并详细记载的有48种10个变种<sup>[2]</sup>。其中,经济价值高的种有欧洲甜樱桃(*P. avium*)、中国樱桃(*P. pseudocerasus*)、欧洲酸樱桃(*P. vulgaris*)、山樱桃(*P. serrulata*)、马哈利樱桃(*P. mahaleb*)、灰毛叶樱桃(*P. canescens*)、草原樱桃(*P. fruticosa*)、毛樱桃(*P. tomentosa*)、欧李(*P. humilis*)等。

樱亚属染色体基数 $x=8$ ,二倍体种之间的基因组大小差异不明显,约为274~371 Mb,三倍体的大叶早樱(*P. subhirtella*)基因组为973.59 Mb,四倍体的中国樱桃基因组大小为1 223.47 Mb<sup>[3]</sup>。甜樱

桃  $2n=16, 24, 32$ , 酸樱桃、草原樱桃  $2n=32$ , 欧李、山樱桃、马哈利樱桃、毛樱桃  $2n=16^{[1]}$ 。染色体类型有4种, 即正中部着丝点染色体(M)、中部着丝点染色体(m)、近中部着丝点染色体(sm)、近端部着丝点染色体(st), 随体常见, 核型类型有2A、2B、1B 3种, 核型类型的分化较不明显<sup>[4-5]</sup>。

国内收集保存樱桃种质资源的单位主要有中国农科院郑州果树研究所、北京市林业果树科学研究所、山东省果树研究所、大连市农科院、西北农林科技大学、四川大学等, 目前共收集樱桃资源500余份。制定了樱桃种质资源描述规范、数据标准和DUS标准<sup>[6-7]</sup>, 用于形状观察鉴定及植物新品种权的申请。

## 2 遗传育种研究

### 2.1 育种技术

主要育种目标: 果实大、品质优、硬肉、丰产、耐贮藏、早实、稳产、不同熟期、自交结实、抗逆性强(耐高温、抗旱、抗寒、抗裂果等)、抗病虫害(耐病毒病、耐流胶病、耐褐斑病等)等。

育种技术常采用自然实生和人工杂交, 通过对种子预处理、精准低温层积、直播成苗和温室营养钵

播种等技术的不断改进, 种子成苗率从5%~30%提高到70%~90%。芽变选种是新品种培育的重要手段, 培育出的品种属于衍生品种, 必须通过试验确定性状变异的幅度, 或获得DNA变异的证据, 并满足樱桃DUS标准的要求。但一些宣称的芽变品种, 不满足相关要求, 并存在欺骗嫌疑。远缘杂交育种多用于砧木育种和种质创新, 并在甜樱桃×中国樱桃、酸樱桃×灰毛叶樱桃、酸樱桃×中国樱桃、甜樱桃×郁李等组合上获得成功, 并培育出‘兰丁’‘京春’等砧木品种。

樱桃倍性育种目前开展工作较少。利用试管苗叶片离体培养加倍技术, 获得了‘吉塞拉6号’的纯合六倍体新种质<sup>[8]</sup>和‘美早’的四倍体新种质(张开春, 私人通信)。

### 2.2 育种成就

2.2.1 新品种选育 1973年旅大市农科所(现大连市农业科学研究所)王逢寿<sup>[9]</sup>育成我国第一个甜樱桃新品种‘红灯’, 因其成熟期早、果个大、颜色紫红、酸甜适口、品质优良、树势强健, 成为我国主栽品种, 栽培面积占我国甜樱桃栽培总面积的40%。

迄今, 国内多家单位先后培育甜樱桃新品种40余个(表1), 储备优系300余个。相信我国选育的品

表1 我国育成的甜樱桃栽培品种

Table 1 Newly released cultivars of sweet cherry in China

育成单位 Breeding Institutes	品种(育成年份) Cultivars (Year of release)
大连市农业科学研究所 Dalian Academy of Agricultural Sciences	红灯(1973)、红艳(1993)、早露(2012)、巨红(1990)、晚红珠(2009)、绣珠(2014)、佳红(1991)、明珠(2009)、蜜泉(2017)、红蜜(1991)、早红珠(2011) Hongdeng (1973), Hongyan (1993), Zaolu(2012), Juhong(1990), Wanhongzhu(2009), Xiuzhu (2014), Jiahong (1991), Mingzhu (2009), Miquan (2017), Hongmi (1991), Zaohongzhu (2011)
中国农业科学院郑州果树研究所 Zhengzhou Institute of Pomology, Chinese Academy of Agricultural Sciences	龙冠(1996)、春绣(2012)、春雷(2017)、春艳(2012)、春露(2017)、春晖(2018) Longguan (1996), Chunxiu (2012), Chunlei (2017), Chunyan (2012), Chunlu (2017), Chunhui (2018)
北京市林业果树科学研究所 Beijing Academy of Forestry Pomology Sciences	彩虹(2009)、彩霞(2010)、香泉1号(2012)、香泉2号(2012)、香泉紫云(2019) Caihong (2009), Caixia (2010), Xiangquan 1 (2012), Xiangquan 2 (2012), Xiangquan ziyun (2019)
山东省果树研究所 Shandong Institute of Pomology	泰山红日(2005)、泰山朝阳(2010)、早甘阳(2013)、齐早(2018)、鲁樱1号(2018)、鲁樱2号(2018)、鲁樱3号(2018)、鲁樱4号(2018) Taishanhongri (2005), Taishanzhaoyang (2010), Zaoganyang (2013), Qizao (2018), Luying 1 (2018), Luying 2 (2018), Luying 3 (2018), Luying 4 (2018)
烟台市农科院果树科学研究所 Yantai Academy of Agriculture Sciences	福星(2013)、福晨(2013)、福玲(2018) Fuxing (2013), Fuchen (2013), Fuling (2018)
河北省农林科学院昌黎果树研究所 Changli Institute of Pomology, Hebei Academy of Agriculture and Forestry Sciences	玲珑脆(2017)、昌华紫玉(2017)、早蜜露(2019)、五月红(2019) Linglongcui (2017), Changhuaziyu (2017), Zaomilu (2019), Wuyuehong (2019)
山东农业大学 Shandong Agricultural University	泰山蜜脆(2011) Taishanmicui (2011)
陕西省果树研究所 Shannxi Institute of Pomology	吉美(2006) Jimei (2006)
浙江省农业科学院园艺研究所 Institute of Horticulture, Zhejiang Academy of Agricultural Sciences	江南红(2018) Jiangnanhong (2018)
烟台市芝罘区林业局 Yantai Zhifu Forestry Bureau	芝罘红(1999) Zhifuhong (1999)

种能比大多引进品种更好地适应我国的栽培条件,并将在生产上逐渐得到应用。比如,大连市农业科学研究院育成‘蜜泉’‘蜜露’‘佳红’等,中国农业科学院郑州果树研究所育成‘春露’‘春雷’‘春晖’等,北京市林业果树研究院育成‘香泉1号’‘香泉紫云’等,山东省果树研究所育成‘鲁樱3号’‘齐早’等,烟台市农业科学院果树科学研究院育成‘福星’等。

在酸樱桃育种方面,西北农林科技大学从匈牙

利引进的野生酸樱桃自然杂交种群中选育了‘玫丽’等4个酸樱桃品种<sup>[10]</sup>。

2.2.2 砧木育种 甜樱桃砧木育种是甜樱桃产业持续健康稳定发展的难点和重点。主要育种目标:适应国内土壤和生态气候条件,促进接穗早实、丰产,树体健壮,抗逆性强,易繁育。通过远缘杂交等途径,先后选育出10余个砧木新品种(表2),为解决“樱桃好吃树难栽”问题做出了贡献。

表 2 我国育成的甜樱桃砧木品种

Table 2 Newly released cultivars of rootstocks in China

育成单位 Breeding institute	品种(育成年份) Cultivar (Year of release)
北京市林业果树科学研究院 Beijing Academy of Forestry Pomology Sciences	兰丁1号(2014)、兰丁2号(2014)、兰丁3号(2017)、京春1号(2014)、京春2号(2017)、京春3号(2017) Landing 1 (2014), Landing 2 (2014), Landing 3 (2017), Jingchun 1 (2014), Jingchun 2 (2017), Jingchun 3 (2017)
山东省果树研究所 Shandong Institute of Pomology	Y1(2009)、矮杰(2018)、矮特(2018) Y1 (2009), Aijie (2018), Aite (2018)
西北农林科技大学 North West Agriculture and Forestry University	CDR-1(2006) CDR-1 (2006)
北京市海淀区植物组织培养技术实验室 Laboratory of Plant Tissue Culture Technology	海樱1号(2012) Haiying 1 (2012)
烟台市农业科学研究院 Yantai Academy of Agriculture Sciences	烟樱3号(2018) Yanying 3 (2018)

### 3 分子生物学研究

#### 3.1 樱桃分子辅助育种

我国科研人员先后利用RAPD、ISSR、SSR等不同分子标记构建了大小分别为634.67 cM和945.96 cM的遗传图谱,平均标记间距分别为12.69 cM和0.96 cM<sup>[11-12]</sup>,其中,以‘晚红珠’×‘拉宾斯’的100个杂交后代构建的遗传群体密度较高,并利用该群体对糖酸比例(数据未公开)、果实大小<sup>[13]</sup>等QTL进行了定位,获得16个与果实大小相关标记,并初步分析得到分布于LG1、LG2、LG6和LG8上的10个果实大小候选基因。

研究出5对SSR标记结合S基因型区分95份甜樱桃品种的标准化技术<sup>[14]</sup>,并且实际用于解决异物同名、同物异名、变种以及遗传倍性混乱等问题。

自交亲和性的DNA鉴定标记来源于花柱决定因子S-RNase和花粉决定因子S基因座F-Box基因(SFB)序列的插入/缺失差异。利用S4'SFB中存在4 bp的缺失开发的S4'选择显性DNA标记<sup>[15]</sup>,可有效鉴定出甜樱桃自交亲和品种。

樱桃果皮和果肉颜色由*PavMYB10.1*的3个等

位基因(*PavMYB10.1a*、*PavMYB10.1b*、*PavMYB10.1c*)控制,利用3个等位基因中存在不同程度缺失开发出甜樱桃果皮颜色选择DNA分子标记,可以在幼苗期判定果皮颜色,进而淘汰非育种目标植株<sup>[16]</sup>。

甜樱桃QTL检测分析主要针对果实品质,如果实质量、硬度、果皮颜色等;与物候有关的性状,如开花时间、成熟期等。

利用重测序和转录组测序可较为全面地获得基因组中的单核苷酸变异(SNP)和简单序列重复(SSR)位点,开发相关DNA标记,加快甜樱桃的遗传研究和育种计划。

#### 3.2 樱桃功能基因与转基因研究

成花机制方面,针对*CO*、*FT*、*LEAFY*等多个成花关键基因及成花相关MADS-box基因在不同时期、不同部位的表达进行检测,并证实不同砧木能够影响接穗中成花关键基因的表达<sup>[17-19]</sup>。

通过小RNA测序,获得了11个与CO<sub>2</sub>处理下参与樱桃果实成熟的miRNA及其对应的靶基因,为进一步研究miRNA在果实成熟过程中的作用及其调控机制提供了更多的信息<sup>[20]</sup>。

转基因技术研究方面,2002年就有利用根癌农杆菌通过叶盘法将抗菌肽M39成功转入樱桃砧木‘Gisela 6’的报道<sup>[21]</sup>,随着不同砧木品种叶片再生体系<sup>[22]</sup>、根再生体系<sup>[23]</sup>、子叶胚再生体系<sup>[24]</sup>的建立,相继有‘考特’‘大青叶’‘对樱’‘CAB-6p’等转基因成功的报道<sup>[25-27]</sup>。将病毒PNRSV的RNAi载体转入‘Gisela 6’后嫁接带有PNRSV的甜樱桃品种,证实转基因砧木可以有效降低接穗中的病毒感染率<sup>[28]</sup>。

此外,对樱桃果实进行病毒诱导基因沉默(VIGS)<sup>[29-30]</sup>研究,可对樱桃果实中颜色以及果实大小相关基因起到沉默的效果,是一种樱桃果实基因功能验证的有效方法。

## 4 樱桃栽培技术研究

### 4.1 甜樱桃适栽条件与种植区划

自20世纪80年代,我国甜樱桃开始规模化商业栽培,至今已形成两个优势栽培区:以山东烟台、泰安,辽宁大连,北京和河北秦皇岛等地为主的环渤海湾地区,和以河南郑州、陕西西安和甘肃天水为主线的陇海铁路沿线区<sup>[31-32]</sup>。此外,在西南高海拔地区和西北地区发展很快,将逐步发展成为甜樱桃产业重要产区。东南地区,如浙江、江苏、上海也在积极引种试种中。我国科研工作者在分析国内外甜樱桃主产区的生态气候特点的基础上,结合环境因子对甜樱桃生长发育的影响,总结出了甜樱桃适宜栽培区的气候土壤条件指标<sup>[33-34]</sup>,进一步明确我国适宜甜樱桃栽培的区域,为种植规划提供直观参考。

### 4.2 苗木繁育技术

我国樱桃栽培发展前期,生产上主要采用实生砧木,导致树体生长不整齐、生产管理不便。无性系砧木的使用很好地解决了这一问题。

樱桃组培快繁体系相对成熟,但生产成本高。‘兰丁2号’‘Y1’‘吉塞拉’等砧木,采用半木质化新梢为插穗、生长素处理、高温高湿环境易于扦插生根。与组培快繁技术相比,扦插技术设施成本和技术门槛低,扦插21 d生根率即可超过70%,育苗成本降低80%,极大促进了我国无性系砧木的规模化生产,使无性系砧木应用比例提高到80%。

### 4.3 甜樱桃整形修剪技术

传统上,樱桃的树形主要有具中心领导干的主干疏层形、有主干的自然开心形和无主干的丛状

形。这些树形结果性状稳定,稳产、丰产、树冠冠幅大、修剪技术复杂、结果晚、用工量大。随着樱桃产业的发展和矮化密植技术推广,一些新树形不断演化出来,如具中心领导干形(Central Leader)的小冠疏层形、纺锤形、改良纺锤形等。小冠疏层形主干高60 cm左右,主枝5~8个,分2~3层,树高3.5 m左右,树冠半圆形;第一层主枝2~3个,留1~2个侧枝;第二层主枝2~3个,2个时留1个侧枝;第三层不留侧枝。纺锤形主枝一般10个以上,不具侧枝,分层或不分层,树冠呈纺锤形、圆柱形或塔形。改良纺锤形是其他树形和纺锤形结合的产物,如基部三主枝改良纺锤形。大连地区的改良疏层形是小冠疏层形通过增加第一层和第二层的主枝数量,而取代侧枝的整形方法。

近年来,为了适应省工、机械作业和规模化种植的需要,试验了一些树冠窄、冠径小、没有主枝的树形。这些树形结构简单、技术容易掌握、标准化程度高。如具有中心领导干的高纺锤形(Tall Spindle Axe, TSA)<sup>[35]</sup>和超细纺锤形(Super Spindle Axis, SSA)<sup>[35]</sup>,中心领导干上没有永久性主枝,而是直接着生结果枝组,二者的区别在于结果枝组的大小不同。多领导干树形,能有效分散树势,如Bi-Axis、Tri-Axis。采用众多直立的大型单轴延伸结果枝组取代永久性领导干,演变出UFO(Upright Fruiting Offshoot)<sup>[35]</sup>和KGB(Kym Green Bush)<sup>[35]</sup>树形。SSA、Bi-Axis、Tri-Axis、UFO由于树冠很窄,整形形成篱壁形,属于2D树形,而非传统的立体3D树形。将中心领导干上水平分布的单轴延伸结果枝组,固定在篱架拉线上,就是水平结果枝篱壁形。

在修剪技术方面,不再强调“因树修剪,随枝作形”,更注重群体叶幕管理,修剪规则越来越简化,修剪机械开始试用,绿篱机对2D树形的夏季摘心试验也在进行中。

### 4.4 生长调节剂在樱桃生产中的应用

目前,生长调节剂在甜樱桃生产中的研究和应用包括:促进生枝、控旺促花、诱导单性结实等。

细胞分裂素、赤霉素等植物生长调节剂都具有促进枝条萌发的效果,配合刻芽处理可实现定位生枝,利于快速形成冠层、调整树体平衡,促进早果丰产。土施1 g·m<sup>-2</sup>多效唑<sup>[36-37]</sup>可有效控制幼树旺长,实现提前丰产。

受花期天气、蜜蜂活动等影响,甜樱桃自然授粉

效果并不稳定,对产量造成很大影响。甜樱桃坐果的关键激素研究<sup>[38-39]</sup>结合生产不断优化调整,已开发出以多种外源激素(赤霉素、细胞分裂素等)和营养物质(氨基酸、海藻素、微量元素等)为主要成分的生长调节剂,可促进甜樱桃单性结实,提高坐果率,为丰产、稳产提供保障。

#### 4.5 土肥水管理

甜樱桃根系生长发育和生理状态受根际环境变化影响。结合樱桃根际土壤特征<sup>[40]</sup>、微生物群落结构特点<sup>[41-43]</sup>,筛选出具有广谱抗生性和促长效应的根际促生菌<sup>[44-45]</sup>及纤维素、酚类物质等外源物料<sup>[46-49]</sup>。起垄栽培模式可有效改善根际土壤环境,利于根系发育和吸收根发生,同时解决了根际积水问题,降低涝害和流胶病的发生。

钙对提高甜樱桃果实品质具有重要作用,果实成熟前喷施钙肥可抑制果胶分解、提高细胞壁强度,从而增加果实硬度、提高贮藏品质,对促进可溶性固形物积累也有显著效果<sup>[50-51]</sup>。此外,土壤中速效钾含量与果实硬度、维生素C含量、粗蛋白含量均呈正相关,而氮素含量与可滴定酸含量呈正相关<sup>[52]</sup>,适当增施钾肥、控制氮肥有利于果实品质提高。

果实发育期,土壤水分不足直接限制果实膨大,土壤湿度变化过大则易引起裂果。水肥一体化条件下,能够得到更佳的土壤肥力、产量和果实品质<sup>[52-53]</sup>。

## 5 甜樱桃设施种植技术研究

樱桃设施栽培可追溯到上世纪90年代,近20年来发展尤为迅速,已形成辽宁、山东、北京、河北、陕西等产区,总面积达1.33万hm<sup>2</sup>,逐渐形成了大连日光温室栽培模式和临朐高架保温大棚栽培模式。

### 5.1 设施结构及栽培模式

大连日光温室一般坐北朝南,东西走向,东、西、北三面为保温墙面,南面为斜面或半拱形采光面,覆盖塑料薄膜。发展初期跨度6~8 m、面积不足666.7 m<sup>2</sup>,目前跨度9.5~12.0 m(最大跨度16 m),脊高4~6 m,单个温室面积1 000~1 333 m<sup>2</sup><sup>[54]</sup>,表面保温层由最初的简易草帘、人工拉盖转变为具有防雨雪、保温好的棉被材质和自动卷帘机设备。通风设施也由人工通风转变为全自动通风设备或排风扇进行调节,更精确地控制棚内温湿度,且节省大量人工。

临朐高架保温大棚,四周无墙体或仅北侧墙体,全拱形或屋脊形,东西或南北走向,棚面覆盖塑料薄

膜,外设电动卷帘式保温被,有单栋式和连栋式两种。设施建造初期,支撑拱形骨架为抗风雪能力较差的竹木材料,一般跨度8~12 m,多为单体大棚。后期发展为钢架结构,跨度增至20 m以上,脊高6 m以上。地炕式加热炉为补充加热方式,与太阳能并用调控棚内环境。

栽培模式主要采用成龄结果树移栽进棚,成活率达95%。采用物理和化学破眠技术提高花期整齐度<sup>[55]</sup>,花果调控技术确保丰产优质<sup>[56]</sup>,肥水一体化技术实现节水、省肥、省工、省力。

### 5.2 产期调节及温湿度精准调控

早期日光温室生产中,11月下旬加覆盖层,晚上通风,温度控制在7.2℃以下,促进树体休眠,12月下旬开始升温,4月初采收上市<sup>[54]</sup>。随着温室结构的优化、破眠剂的使用<sup>[57]</sup>以及10月中下旬多项促休眠措施的应用,目前在大连瓦房店地区11月上中旬开始升温,果实2月初开始成熟,比发展初期提前60 d左右。

采用的温湿度控制技术要点:升温初期白天温度控制在18~20℃,最高不超过25℃,夜间顺其自然,湿度保持在80%;花期白天温度控制在16~18℃,夜间温度控制在5~8℃,湿度40%~50%;果实膨大期白天气温控制在21~23℃,夜间温度控制在7~10℃,湿度60%;果实成熟期白天气温控制在20℃左右,夜间温度控制在10℃左右,湿度不超过50%。

## 6 樱桃病毒病及其防治研究

樱桃病毒类病害主要通过嫁接等营养繁殖手段传播,且能通过维管束系统侵染樱桃树体,全世界樱桃能被64种已知病毒、类病毒和植原体感染,我国鉴定明确能侵染樱桃的病毒有20余种<sup>[58-59]</sup>,主要包括:李属坏死环斑病毒(*Prunus necrotic ring spot virus*, PNRSV)<sup>[60]</sup>、李矮缩病毒(*Prune dwarf virus*, PDV)<sup>[61]</sup>、樱桃绿环斑驳病毒(*Cherry green ring mottle virus*, CGRMV)<sup>[62]</sup>、樱桃小果病毒-1(*Little cherry virus 1*, LChV-1)<sup>[63]</sup>、樱桃小果病毒-2(*Little cherry virus 2*, LChV-2)<sup>[64]</sup>、樱桃病毒A(*Cherry virus A*, CVA)<sup>[65]</sup>、樱桃坏死锈斑驳病毒(*Cherry necrotic rusty mottle virus*, CNRMV)<sup>[66]</sup>、樱桃锉叶病毒(*Cherry rasp leaf virus*, CRLV)<sup>[67]</sup>、黄瓜花叶病毒(*Cucumber mosaic virus*, CMV)<sup>[68]</sup>、李树皮坏死茎纹孔伴随

病毒 (*Plum bark necrosis stem pitting-associated virus*, PBNSPaV)<sup>[69]</sup>、啤酒花矮化类病毒 (*Hop stunt viroid*, HSDV)<sup>[70]</sup>、枣疯病植原体 (*Candidatus Phytoplasmas ziziphi*, 16SrV-B)<sup>[71]</sup>等。

采用 RT-PCR、多重 RT-PCR<sup>[72-73]</sup>、荧光定量 PCR、反转录环介导扩增技术 (Loop-mediated isothermal amplification, LAMP)<sup>[74]</sup>、小 RNA 高通量测序和转录组测序等手段进行病毒检测,通过小 RNA 高通量测序获得了 LChV-1、LChV-2、CVA、CLBV、PBNSPaV、ASGV、PNRSV<sup>[75-77]</sup>7种樱桃病毒的全基因组序列,为甜樱桃病毒病精准诊断奠定了坚实的科学基础。

‘红灯’‘美早’等品种对 LChV-1、LChV-2、CVA 和 PBNSPaV 病毒较为敏感,‘红灯’至少感染 LChV-1、LChV-2、CVA、CLBV、PBNSPaV、PNRSV、ASGV 等 1 到 7 种病毒、类病毒或植原体,感染率达 88.7%,甚至出现了“公树病”和“小果病”等现象<sup>[78]</sup>。

通过热处理、分生组织培养脱毒快繁和超低温冷冻脱毒技术可获得樱桃无病毒原种苗。无病毒苗木繁育可根据樱桃无病毒苗木繁育技术规范 (河南省地方标准) 操作<sup>[79]</sup>。

## 7 樱桃贮运与加工技术研究

甜樱桃果实为非呼吸跃变型水果,但它是典型的高呼吸代谢水果,采后腐烂迅速,不耐贮运,粗略估计采后损失在 20% 左右。近年有关甜樱桃采后研究工作主要集中在果实贮藏腐烂病害控制技术<sup>[80-82]</sup>和采后贮运技术<sup>[83]</sup>等方面。

果实腐烂病害控制技术方面。低温处理<sup>[84]</sup>通过降低呼吸作用,减缓生理代谢,同时抑制病原微生物的活度,是最基本的防病方法<sup>[80-81]</sup>。但单一低温无法控制低温菌的萌发,需要结合保鲜剂处理。在 1996 年以前,专门作为樱桃采后保鲜处理的化学药剂是 Iprodione<sup>[85]</sup>。2000 年以后采用过乙酸 (PAA)<sup>[86]</sup>、1-MCP<sup>[87]</sup>、1%CaCl<sub>2</sub> 和 NaHCO<sub>3</sub><sup>[88]</sup> 等相对比较安全的保鲜技术,但效果有限。SO<sub>2</sub> 和 ClO<sub>2</sub><sup>[89]</sup> 则存在化学残留安全隐患。后来尝试过乙醇熏蒸、EBR 处理<sup>[90]</sup>、丙酮酸乙酯<sup>[91]</sup>,或将各类保鲜剂联合使用,如 1-MCP 和 ClO<sub>2</sub><sup>[92]</sup> 联合处理等化学方式,均因对公众健康以及环境因素的考虑而逐渐受到了限制。生物拮抗微生物等生物方法限于防病效果的持续性及经济成本,还未规模化应用。物理防控方式,如采用电子束辐

照技术<sup>[93]</sup>、短波紫外<sup>[94]</sup>,但防病效果有限。

目前生产中仍以 MA 保鲜技术为主,其关键在于包装薄膜材料<sup>[95]</sup>。CA 技术<sup>[96]</sup> 由于受到成本及维护技术限制,较少应用。移动式气调箱可以兼具 MA 和 CA 技术优势,对樱桃的物流保鲜效果尤为显著<sup>[97-99]</sup>。樱桃的其他保鲜技术研究还包括冰温贮藏技术<sup>[100]</sup>、减压贮藏技术、涂膜保鲜技术等。

目前,我国樱桃主要以鲜食为主,产业化加工产品较少,主要以研究居多,产品主要包括樱桃酒、樱桃汁、樱桃果醋、樱桃罐头、樱桃酱及樱桃脯等。

## 8 问题与展望

我国樱桃科研工作的主要问题在于科研立项困难。管理层基于抓大放小的传统观念,樱桃产业科技问题被严重忽略了,经费投入严重不足,造成科研人才流失,除育种领域外,很多领域处于生产经验总结阶段,还有许多研究方向几乎空白,严重影响了产业的健康发展。建议加大科研经费投入,将樱桃资源圃列入国家种质资源支持系统,加强资源普查和收集保存工作;持续支持育种工作,开展品种/砧木区域化试验;研究配套栽培技术,示范轻简化、标准化栽培技术;扶持贮运加工产业化;尽快填补病虫害应急防控等空白点。

我国樱桃遗传资源丰富,为种质创新、突破性育种工作提供了得天独厚的条件。德国利用我国原产的灰毛叶樱桃做亲本培育了著名 ‘Gisela 3’ ‘Gisela 5’ ‘Gisela 6’ ‘Gisela 12’ 等砧木,英国利用中国樱桃培育出 ‘考特’ (‘Colt’, *P. avium* × *P. pseudocerasua*)。利用野生资源,俄罗斯利用山桃稠李杂交培育出 ‘Krymsk 5’ (*P. fruticosa* × *P. lannesiana*)、‘Krymsk 6’ [*P. cerasus* × (*P. cerasus* × *P. maackii*)], 美国利用 ‘马哈利’ 培育出 ‘M×M’ 砧木 (*P. mahaleb* × *P. avium*), 远缘杂交成为培育砧木的主要途径。在甜樱桃新品种育种方面,利用野生资源和远缘杂交技术,德国和美国都培育了有价值的新材料 (Mirko Schuster, 私人通讯)。

广阔的樱桃栽培地域范围,延长了樱桃鲜果供应期,大田樱桃上市期从西南高海拔地区的 4 月下旬,持续到大连、青海的 7 月初。通过优质晚熟品种的种植,在一些夏季凉爽地区,采收期还能进一步推迟。近年来,大果优质樱桃持续畅销,将带动樱桃优质栽培的发展。樱桃设施栽培,由于生产的鲜果品

质远超露地栽培,上市期在2月至5月初,属于全球供应淡季。此外,设施栽培能有效规避恶劣天气影响,且丰产稳产,病虫害少,经济效益显著,发展潜力巨大,将进入快速发展阶段。露地栽培和设施栽培,使国产甜樱桃鲜果上市期长达6个月,奠定了市场培育和品牌打造的基础。

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