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内 容 简 介

本书系中国园艺学会猕猴桃分会学术及产品发展研讨会论文集，是继《猕猴桃研究进展》前三集之后出版的第四集。全书共分为资源及保护利用、育种与新品种试验、高效栽培与病虫害防治、生物技术与生理生化、贮藏保鲜与深加工、国内外市场开拓、新技术应用七个专题，较全面地反映了国内及世界猕猴桃主产国近年来猕猴桃研究与产业发展的动态。

本书可供从事猕猴桃产业及科研的人员、农业院校师生、果树推广和管理工作者参考。

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《猕猴桃研究进展(IV)》编委会

序　中国猕猴桃科研和产业的崛起及可持续发展

世界猕猴桃的科研和生产正发生着巨大而深刻的变化，中国作为猕猴桃属植物的原产地和栽培猕猴桃品种的源头资源发祥地，曾孕育了全球猕猴桃产业的发端。虽然在猕猴桃引种驯化 100 余年的历史中，我国曾经在相当长的时期落后于新西兰和意大利等猕猴桃科研及生产大国，但近 20 年来，中国的猕猴桃科学家和企业家已经改变了当今全球猕猴桃的科研和产业格局。

在科研方面，20 年前在猕猴桃科学文献中几乎很难查到中国的资料和信息，如今出自中国的猕猴桃科学论文和研究报告占到了全球的约 1/4。在猕猴桃属植物生物学研究的许多方面，中国被公认为是世界的研究中心(Huang and Ferguson，2007)。在猕猴桃产业方面，中国目前栽培面积约 6 万公顷，占世界栽培总面积 12 万公顷的 50%，已经远远超过了意大利(2.1 万公顷)、新西兰(1.2 万公顷)和智利(8 千公顷)。在全球猕猴桃 150 万吨的年产量中，我国猕猴桃的年产量约 40 万吨，占 27%，与意大利产量(约 40 万吨)持平，且超过了新西兰(28 万吨)和智利(15 万吨)(Belrose Inc，2005)。其产量较低的原因除了我国目前有 20% 的幼年果园外，是我们猕猴桃果园的管理水平离高产优质还有一定差距。

中国猕猴桃科研和产业崛起将更深远地影响世界猕猴桃产业还在于，我国 20 年来立足于本土猕猴桃遗传资源研究及其新品种的选育，中国选育的中华猕猴桃(*Acitindia chinensis*)黄肉新品种在全球范围广泛栽培，彻底改变了世界猕猴桃产业单一品种格局，推动了猕猴桃市场多样化和消费的多元化、改变了全球猕猴桃产业依赖单一新西兰品种——‘海沃德’的局面(Huang and Ferguson，2003；Huang and Ferguson，2007)。中国人花了 20 年时间成功实现了中华猕猴桃由野生到大规模商业栽培的驯化过程。世界猕猴桃栽培品种的构成已由 20 多年前的单一物种和品种(*A. deliciosa*‘Hayward’)改变至如今 15% 为中华猕猴桃品种、85% 为美味猕猴桃(*A. deliciosa*)品种。国内猕猴桃生产，中华猕猴桃品种栽培则高达 24%。具有我国自主知识产权的中华猕猴桃新品种——‘金桃’(*A. chinensis*‘Jintao’)通过专利使用权转让，在欧洲及南美地区广泛栽培有效地均衡了新西兰 20 世纪 70 年代通过获取中国猕猴桃资源，选育的中华猕猴桃新品种——‘Hort16A’控制全球黄肉猕猴桃品种生产的局面。虽然目前新西兰国内栽培的中华猕猴桃黄肉品种(*A. chinensis*‘Hort16A’)通过高接换种和新建果园达到了 20% 的产量；而我国选育的红肉猕猴桃新品种——‘红阳’，再次异军突起，逐步形成了国际猕猴桃市场中绿果、黄果、红果的多样化格局。我国在猕猴桃遗传资源发掘及其新品种选育的成就将引领国际猕猴桃科研及产业发展，对世界猕猴桃产业的可持续发展具有极其重要的意义。

但是，我们必须清醒认识到我国猕猴桃产业中还存在众多问题，我国在果园管理及其优质高产栽培技术还落后于新西兰和意大利；相关遗传改良研究、基因组及其基因调控研究、果树生理生化研究、整型修剪技术、科学管水和施肥技术、果园病虫害防治、果品营养与健康等研究缺乏长期稳定的科研投入机制，支撑产业升级的研发体系相对薄弱。总体看我国猕猴桃科研与产业存在如下问题：① 我国作为猕猴桃资源和栽培的双重大国，针对产业发展的应用性基础研究滞后，研究部署不合理、针对产业升级的研究有待加强；② 我国丰富而宝贵

的猕猴桃资源依然流失国外，而国内在农业作物遗传改良研究的科研投入则主要集中在粮棉油大田作物，对诸如猕猴桃等经济作物的自我研发支持力度不够，丰富的资源优势远没充分发挥，资源发掘的广度和深度有待加强；③ 产业规划滞后、产业目标导向有待提高；④ 以企业为主体的技术研发体系尚未形成，制约了产业的可持续发展，尤其是中国猕猴桃产业面向世界的合力急待改善；⑤ 我国目前虽然具有栽培品种多的优势，但市场品牌和精品意识不够，中国猕猴桃产品面向世界市场的推介及市场战略相当薄弱，中国猕猴桃产品在国内外市场基本处于无序状态，同时，猕猴桃消费导向研究及消费市场培育基本空缺。

促进我国猕猴桃科研和产业稳步健康发展，是我国猕猴桃工作者义不容辞的责任。我国猕猴桃科研和产业的可持续发展急需解决如下问题：

(1) 加强以企业为主体的技术研发体系的建设，鼓励科研院所、大学积极参与企业发展相关的研发活动，引导科研单位与企业的共建猕猴桃研发中心，致力于猕猴桃产业发展的研发和产品升级的全球竞争，全面推进中国猕猴桃产业高水平、高起点的进入国际市场。

(2) 充分发挥我国的猕猴桃资源优势，加强野生资源研究、发掘优异基因型和研发特异新品种。立足我国资源优势、建立优异基因型资源库(圃)、掌握品种育种改良资源的源头是我国长期主导国际猕猴桃产业发展的立足点。

(3) 加强我国猕猴桃产业以企业为主体的产业规划、明确产业目标是我国目前猕猴桃产业发展的当务之急。通过规划，形成全国产业协会—研发支撑体系—市场营销协调的整体部署。加强精品战略、形成特色市场，同时，加强猕猴桃消费导向及消费培育的相关研究。

(4) 加强针对产业发展的应用基础研究，重点解决中国特定气候条件下的果园优质高产栽培技术、采后包装、储运技术及加工技术，形成中国产业技术规范体系，支撑产业的可持续发展。

(5) 以国家及地区重大计划为牵引，如新农村建设，组织联合攻关项目，加强能力建设、培养猕猴桃科研人才及生产第一线果园管理技术人才，造就我国面向新世纪全球猕猴桃产业的科研和产业的人才队伍。

中国猕猴桃科研及产业崛起举世瞩目，我国的猕猴桃科研工作者、企业家和种植者为当今猕猴桃产业作出了巨大贡献，未来世界猕猴桃产业的可持续发展很大程度上将依赖于中国丰富的猕猴桃资源和中国人的智慧。中国猕猴桃科研工作者将任重道远。

中国园艺学会猕猴桃分会理事长　黄宏文
2007 年 10 月 4 日于武汉东湖磨山

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（一） 资源及保护利用

种质资源性状描述和评价的必要性

——以猕猴桃为例

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摘 要 遗传资源能为育种和植物改良提供原材料，那些有一定的或者完全没有改良经验的植物育种专家都倾向于最大限度地利用所收集的原始的或未经过人工改良的种质资源来进行育种。猕猴桃跟其他植物有些特别，经过人工选择的影响力很小，即仍然很接近野生植物。为了充分利用猕猴桃属植物的遗传多样性，育种专家需要更深入地了解物种的多样性，同样也要能够鉴别他们所使用材料的正确性。试验中所采用的所有植物都应制作实物标本。对猕猴桃属不同植物的繁殖生物学掌握得越多，越有利于将野生猕猴桃种质合理应用到猕猴桃育种计划中来。新西兰园艺研究所猕猴桃资源收集圃已证明了它在猕猴桃有价值新品种开发中的作用。

关键词 猕猴桃属(*Actinidia*) 育种 种质资源 繁殖生物学 倍性

The Need for Characterisation and Evaluation of Germplasm: Kiwifruit as an Example

1 Introduction

Germplasm collections provide the raw material for programmes of plant breeding and crop improvement. This is often their prime function, the main reason for their initial collection, usually by breeders, and it is the genetic diversity and the occurrence of particular desirable genes that are of greatest interest to plant breeders. However, germplasm collections are not used solely by breeders: other biologists will have different interests and possibly different requirements (van Treuren and van Hintum, 2003). While breeders will focus on characters of immediate perceived value, other biologists may be more interested in the potential variation or will use the collections to understand better the properties and behaviour of the plant, especially at the genomic level.

Breeders of plant species that have little or no history of improvement tend to make the greatest use of collections of raw or unimproved germplasm. Kiwifruit (*Actinidia*) are one such crop in that they have been subjected to little selection pressure and are still very similar to plants in the wild. The most widely grown commercial cultivar, ‘Hayward’ (*A.deliciosa*), is only two or three generations from the wild as is ‘Hort16A’ (*A.chinensis*). The current Chinese kiwifruit cultivars are nearly all selections directly from the wild and are not the products of planned breeding programmes (Huang and Ferguson, 2007). Kiwifruit breeders are therefore in a very different situation from, for example, maize breeders where the inbred lines used today are the

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product of several centuries of germplasm enhancement and recurrent selection (Anderson and Brown, 1952).

Effective exploitation of wild or unimproved germplasm for crop improvement demands comprehensive studies of its reproductive biology (Stalker, 1989). Although the recent advances in population genetics, genomics and bioinformatics improve our understanding of diversity and will change the ways in which we exploit that diversity, there is a danger that we will forget the fundamentals. We still need botanists, horticulturists, agronomists, plant breeders and plant pathologists. We need to know about genes, genomes and the gene pools, but we still need to know about the plants as well, we need to know what diversity exists, just as we need to know which aspects of that diversity should be chosen for incorporation into breeding programmes. The HortResearch *Actinidia* (kiwifruit) germplasm collection in New Zealand is used as an example to justify why I believe it is so important for us to continue studying both the basic biology and the commercial prospects of the plants we are using in breeding programmes.

2 The HortResearch *Actinidia* germplasm collection

The first introduction of *Actinidia* germplasm into New Zealand was in 1904 and, although some other material was imported at about the same time, probably indirectly from the same source in China (Ferguson and Bollard, 1990), the next documented importation was in 1955 by the Department of Scientific and Industrial Research when several different *Actinidia* species were imported from Hillier's nursery in England. Since about 1975, there has been an active policy of improving our germplasm collections and we now have an extensive range of material that we want to conserve on a long-term basis:

? genotypes raised from seed or budwood of species in the wild;

? genotypes from other *Actinidia* germplasm collections;

? cultivars from New Zealand or elsewhere in the world, irrespective of whether they are still grown commercially;

? elite breeding lines;

? advanced selections from our breeding programmes;

? genotypes, no matter what their origin, which are kept simply because they show interesting or unusual characteristics.

To date, 300 accessions have been imported from overseas by purchase, by gift or by exchange (Table 1), there is material of another 40 accessions waiting clearance through quarantine (Table 2), and almost 360 further seed accessions still held in bond. These accessions have been imported from countries where *Actinidia* grow wild, such as China, Japan, Korea and Russia, as well as different countries to which *Actinidia* material was sent early last century, although in such cases the original provenance is usually not known. Currently the collection holds about 3500 distinct genotypes of which nearly 1000 have been selected for long-term retention.

Nearly all these selections are from importations of unimproved germplasm and the HortResearch kiwifruit breeding programmes are largely dependent on these wild plants whereas breeders of many other crops are much more reliant on existing collections, especially on proven elite breeding lines or on old commercial cultivars. Programmes of progeny testing mean, however, that we are now at the stage of accumulating good breeding lines and elite parents. There are also about 80 cultivars and named selections, some of which came from overseas. In addition, we hold budsports or mutations which have appeared on commercial kiwifruit orchards. These have very little value in their own right but can be of great potential value for breeding programmes. A good example would be the "fruiting males" or "inconstant males", which produce very small fruit as well as viable pollen (McNeilage, 1991). The fruit are too small to have any commercial value as such but the fruiting males were the starting point for the programme to produce truly hermaphroditic kiwifruit cultivars (McNeilage et al., 2006). It is therefore important to conserve such gender variants. Another example would be the occasional budsports of *A.chinensis* 'Hort16A' that have spontaneously doubled in chromosome number: again, these seem to have little obvious commercial value but could allow greater flexibility in breeding programmes.

Table 1 Imported *Actinidia* plants released from quarantine and established in the HortResearch *Actinidia* germplasm collection

Taxon	Accessions	Genotypes	Selections
A.arguta	27	171	31
A.arguta purpurea	6	80	4
A.callosa henryi	2	22	1
A.chinensis	90	955	456
A.chrysantha	3	12	12
*A.deliciosa deliciosa**	131	1975	258
A.deliciosa chlorocarpa	1	7	7
A.deliciosa coloris	1	17	17
A.eriantha	5	60	37
A.fortunatii	1	1	1
A.fulvicoma lanata	2	2	2
A.guilinensis	4	19	19
A.hemsleyana	1	1	1
A.hypoleuca	1	1	1
A.indochinensis	1	18	18
A.kolomikta	3	3	3
A.lanceolata	1	9	9
A.latifolia	1	17	17
A.macrosperma	4	5	5
A.melanandra	5	5	5
A.polygama	13	70	17
A.rufa	4	28	16
A.setosa	2	2	2
A.valvata	1	2	2
Total	310	3482	941

* Including 13 accessions and 339 genotypes of a possibly distinct but closely related variety or species

Table 2 *Actinidia* plants requiring virus testing before release from quarantine for establishment in the HortResearch germplasm collection

Taxox	*A.callosa*	*A.chinensis*	*A.deliciosa*	Total
Accessions	2	6	34	42
Genotypes	30	81	383	494

Other *Actinidia* germplasm collections in China hold a greater range of *Actinidia* species but the HortResearch collection would be easily the most comprehensive for the two most important commercial species, *A.chinensis* and *A.deliciosa*. We have 90 accessions of *A.chinensis* released from quarantine, three new accessions requiring virus testing and 273 further accessions of seed held in bond; in total, we have about 1000 genotypes of *A.chinensis* in our germplasm collection. There are also 120 accessions of *A.deliciosa* released with living genotypes established, 34 new accessions requiring virus-testing, and a further 73 accessions of seed held in bond. We have about 2000 genotypes of *A.deliciosa* in the collection, but most of these come from two provinces of China, Chongqing and Sichuan, whereas the species occurs naturally in at least seven other provinces (Liang, 1983). In theory, it is desirable to collect from wild populations that are well dispersed and that occur in different environments. In practice, however, the collections are not necessarily representative of what is in the wild: instead, they are simply what it has been possible to acquire.

Apart perhaps from *A.arguta*, *A.eriantha* and *A.polygama*, the collections of other species are very patchy and in some cases we have only a single plant or have plants of only one gender. There is a danger that when we have only a very small number of genotypes for a particular taxon, those genotypes may be incorrectly assumed to be typical of the taxon as a whole.

For many years the emphasis in kiwifruit breeding was very strongly on *A.chinensis* and *A.deliciosa* and other species were often considered as being primarily of academic interest. It is now better accepted that these other species could be the source of attributes which might lead to the production of completely new and different types of kiwifruit: we need more representatives of these species.

Although 300 accessions may seem very few to those used to dealing with crop germplasm collections often containing tens of thousands of accessions, the HortResearch *Actinidia* collection would be amongst the larger of such fruit tree germplasm repositories. For example, the staff of the German Fruit Gene bank at Dresden-Pilnitz consider that, with about 350 accessions of nearly all *Malus* species, they have one of the largest ex situ collections of *Malus* wild species in the world (Geibel and Hohlfeld, 2003). There are, of course, other large collections of *Malus* cultivars.

The kiwifruit germplasm plants are routinely grown on T-bar structures and they are trained as if they were commercial kiwifruit vines. Most species grow very well under such conditions. The collection is held on HortResearch orchards and occupies about 6.2 ha (1.1 ha at Kerikeri, 3.83 ha at Te Puke, 1.27 ha at Riwaka), including the area occupied by populations of seedlings from seed accessions. Many genotypes are replicated at the different orchards. This reduces the risk of losing significant parts of the collection to disease or natural disasters. So far, the possibility of longterm storage of *Actinidia* as seed, in vitro, or cryogenically has not been investigated.

The collection is supported by a comprehensive, relational, computer-based database system which contains information on individual accessions such as source, provenance, date of acquisition, quarantine status, import permit number, taxonomic status, voucher specimen numbers, genders, ploidy determinations, and precise geographic location in the research orchards. Accessions are given a coding based on taxon and chronological order of introduction for that taxon. Individual genotypes within an accession are given a selection number and their gender, ploidy, and fruit characteristics (for female vines) are recorded. This is all time-consuming but makes the collection that much more useful.

3 The need for germplasm

3.1 History of kiwifruit as a cultivated plant

Kiwifruit are amongst the most recently domesticated of fruit plants (Ferguson and Bollard, 1990; Huang and Ferguson, 2007). Apart from a few unimportant exceptions, the first *Actinidia* were taken into cultivation towards the end of the 19th century and the early years of the 20th century. The most important commercial species of kiwifruit, *A.deliciosa*, was apparently in cultivation by 1899 and the first seed of this species were brought to New Zealand in 1904. Until about 10 years ago, most kiwifruit grown commercially anywhere in the world were descended from that first importation of seed, and could be traced back to one male and two female kiwifruit plants (Ferguson and Bollard, 1990). Worse, commercial orchards almost everywhere grew exclusively one fruiting cultivar, 'Hayward'. The only important exceptions at that time were the polliniser or male used in Californian kiwifruit orchards and the cultivars then being planted on a small scale in China. An industry based on such a narrow genetic base, with a single, vegetatively propagated fruiting clone, is very vulnerable to new pests and diseases.

This has been demonstrated in other cultivated plants with similar dangerously narrow genetic bases. Virtually all the coffee plants that are grown in the Americas, *Coffea arabica*, are descended from a single plant taken from Java to Amsterdam in 1706. One consequence was that the cultivars grown through Central and South America had little or no resistance to coffee leaf rust (*Hemileia vastartrix*) when it arrived in Brazil in 1970 (Wrigley, 1995). Another salutary example is the susceptibility of the many maize cultivars containing a form of male cytoplasmic sterility to a race of the fungus *Helminthosporium maydis* (Goodman, 1995). A closer parallel is the recognised vulnerability in the United States of tree or vine fruit crops such as almonds, apples, apricots, cherries, grapes, nectarines, peaches and walnuts, because of their limited genetic bases and because only a few cultivars of each are grown (Committee on Managing Global Genetic Resources: Agricultural Imperatives, 1993). Geographic concentration, as is the case of the New Zealand kiwifruit industry, combined with genetic uniformity also increases vulnerability to adverse weather (Iezzoni, 2005).

The vulnerability of the main commercial cultivar of kiwifruit to pests or diseases remains, fortunately, a potential threat although it should not be dismissed. A more immediate threat a decade ago was that as kiwifruit cultivation spread around the world; New Zealand was losing its competitive advantage: it was going from being the only producer of exported kiwifruit to becoming only one of the countries all growing and exporting kiwifruit of the one cultivar, 'Hayward'. This problem was partially overcome by the introduction of the ZESPRI™ branding (Beverland, 2001). There was another threat, however, that fickle consumers might become bored with the traditional kiwifruit with its brown hairy skin, green flesh and mild, but rather acid flavour. The solution to this problem was more radical: take advantage of the diversity within the rest of the genus *Actinidia* and produce distinctive, new, protectable cultivars.

3.2 Genetic diversity in *Actinidia*

Within *Actinidia* there is great diversity in infructescence size, and in fruit characteristics such as size, shape, skin colour, skin hairiness, skin toughness and palatability, flesh colour and texture, flesh flavour and chemical composition, time of maturity (and hence harvest), storage life and shelf life as well as changes in skin or flesh colour and in flesh texture during ripening (Huang et al., 2004; Huang and Ferguson, 2007). There is likewise great diversity in other attributes such as growth habit and vigour, climatic and edaphic requirements, time of budbreak and of flowering, disease susceptibility and yield potential; even ease of vine management. Furthermore, within a single species there can be considerable diversity. Although genotypes of the one species might be