



The Genus ACTINIDIA A World Monograph

HUANG Hongwen

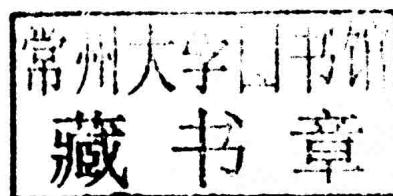


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Foreword

I first started working on kiwifruit about 1975. Kiwifruit were then a very minor crop. There were perhaps 1000 ha of commercial kiwifruit orchards in New Zealand, mostly recently planted, and as New Zealand was then the only country with significant plantings, this meant there were about 1000 ha of commercial kiwifruit orchards throughout the world. Kiwifruit were still a uniquely New Zealand crop and the kiwifruit in world trade all came from New Zealand.

Scientists in New Zealand knew the kiwifruit as the “Chinese gooseberry” since the new name of “kiwifruit”, first devised for the export trade, had not yet achieved universal acceptance. We had a collection of some of the old kiwifruit cultivars—although by this time ‘Hayward’ was becoming dominant—and representatives of a few *Actinidia* taxa obtained from the nursery firm of Hillier and Sons in the United Kingdom: several genotypes of *A. arguta*, including one then classified as *A. arguta* var. *purpurea*, and single male plants of *A. callosa* var. *henryi*, *A. hypoleuca* and *A. melanandra*.

We knew that kiwifruit came from China—hence the old common name Chinese gooseberry—but little more. Reading the taxonomic treatment of *Actinidia* by Li Hui-Lin made it obvious that there were many species and varieties in China and that the diversity in the genus was much greater than suggested by the few taxa we had seen. However, the literature on the genus was very scattered, often in journals that were not available to us and frequently in languages we could not read. Hence we had a very narrow view of the kiwifruit and its relatives.

The scientific research was also very narrow and

limited. Almost all the research on kiwifruit as a crop plant was carried out in New Zealand and by only a few people—five or six of us could meet and between a late morning tea and an early lunch we could quickly summarise the priorities for research and discuss what research was actually being undertaken, almost always in New Zealand.

Since then, of course, the cultivation of kiwifruit has expanded rapidly so that today the area throughout the world of commercial kiwifruit orchards is nearly 150,000 ha and total annual production about 2.5 million tonnes. Kiwifruit are no longer a uniquely New Zealand crop but are cultivated in a number of countries. In 1975, kiwifruit in China were almost entirely collected from the wild. Today, China has more kiwifruit orchards and produces more kiwifruit than any other country.

Furthermore, the kiwifruit available to consumers are no longer all brown and hairy on the outside and green inside. Different cultivars are appearing in the marketplace with a range of flesh colours—green, yellow or red—and with rather different flavours. Many of the older cultivars were simply selections from the wild, but increasingly the newer cultivars are the result of planned breeding programmes, sometimes even involving interspecific hybridization.

As kiwifruit cultivation and production have expanded, so too has the research on kiwifruit and the other *Actinidia* species. This year the 8th International Symposium on kiwifruit will be held at Dujiangyan in Sichuan. This is the second time that the symposium has been held in China and it emphasises the greatly increased importance and sophistication of Chinese research on kiwifruit. A good example

is the work that has resulted in a much better understanding of the relationships between taxa in the *Actinidia chinensis* complex and the gene flow between them.

There have been several books and many detailed reviews of different aspects of kiwifruit biology and cultivation. "The Genus ACTINIDIA, A World Monograph" is the most welcome addition to literatures, as it brings together knowledge from both China and the rest of the world and also, most important, takes into account the taxonomic and nomenclatural changes.

"The Genus ACTINIDIA, A World Monograph" demonstrates just how much we have learnt over the past 40 years.

From knowing almost nothing of the wild kiwifruit we now have detailed and comprehensive information on the different *Actinidia* taxa, their distributions, the relationships between them and their commercial potential. The many illustrations will also be of great assistance.

Professor Huang Hongwen and his colleagues are to be congratulated on their notable achievements. I can only regret it was not available when I first started my work. "The Genus ACTINIDIA, A World Monograph" is an essential reading for anybody interested in kiwifruit and the other *Actinidia* species. It provides a secure foundation for further research as there is still a great deal we have yet to learn about this important crop.

Ross Ferguson

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Preface

Kiwifruit is a most successful paradigm of plant domestication in the 20th century, from a wild fruit to current worldwide commercial cultivation in only 110 years. I am proud to say that the kiwifruit (*Actinidia chinensis*) and most species of genus *Actinidia* are endemic plants to my homeland. My research in *Actinidia* as an *Actinidia* germplasm hunter and breeder began in 1979 that took me through 35 years of experience and progress. This includes participating in a national *Actinidia* germplasm survey, collection and inventory, capacity building repositories, germplasm evaluation and breeding and commercialization of kiwifruit industry in China. I am most grateful to the guidance of my senior teachers and the support from many colleagues. My longtime dedicated efforts in many studies from germplasm evaluation & exploration, repository management, population genetics and breeding to fundamental biological questions not only progressively depended my understanding on genus *Actinidia*, but also rendered personal enjoyment and contentment. The history of the kiwifruit domestication dated back to 1904 when *Actinidia chinensis* var. *deliciosa* was introduced into New Zealand from China. Initial domestication was accomplished in New Zealand and worldwide commercial production began in 1970s by a single kiwifruit cultivar 'Hayward'. As for *Actinidia chinensis* var. *chinensis*, tremendous efforts by Chinese kiwifruit researchers on native germplasm exploration and breeding successfully domesticated this variety for commercial production during the past 35 years. The efforts and accomplishments are highly valued worldwide and is a pride of Chinese *Actinidia* researchers.

I had an experience during my Ph.D. training and practice in plant genetics and breeding in the U.S. from

late 1980s to 1990s when I marveled at vast literatures in the university libraries. I became deeply interested in the many classic works of Burbank (1849–1926) and Michurin (1885–1935), two great masters of plant breeding, especially their working notes on exploring plant natural resources and breeding ideas. Those works profoundly impressed me with their ways of thinking and breeding approaches. Thus, the starting point of any plant domestication and breeding for genetic improvement is fundamentally based on in-depth understanding and acquired knowledge of basic biology, variation patterns and processes and interactions between genetics and the environmental. Basic knowledge such as taxonomy, natural distribution, breeding system, inheritance, selection efficiency and hands-on practices are critically important for plant breeders. China is the second richest country for plant diversity including many native crop plants, "Learn from history, Learn by analogy" should help propel us forward.

In the late 1990s, I became a principal investigator and Ph.D. advisor and began my responsibility of strategic planning for the multi directional research of this Chinese endemic genus. Thanks to the previous experience in natural resource surveys guided by my teachers and my footprints on almost all main natural distribution ranges, although still felt "A leaf before the eye shuts the sight of Mount Tai", my expedition and observation notes are quite extensive. Moreover, after many research programs implemented, progresses achieved, and many graduate students trained, the information database on *Actinidia* has enlarged extensively, broadening our understanding and knowledge. Since 2000, I have edited six volumes (Advances in *Actinidia* Research I–VI), and reported a number of research papers and re-

views. In the past 10 years, my colleagues and I have been recognized nationally and internationally in research on *Actinidia* resources and taxonomy, population genetics, breeding and cultivar improvement. Thus, a monograph of the genus *Actinidia* became a priority of my agenda. However, besides my longtime research in *Actinidia*, I have also been a director of botanical gardens for the past 18 years, along with heavy workloads in routine administration. Hence, the writing of this monograph was on and off since 2004 when I drafted the outline. Completion of the monograph took much longer and was more difficult than I had initially expected. As such, it took eight years to completion owing to indomitable and tireless efforts, including those of my students and colleagues. Nonetheless, it was worth “spending eight years grinding this sword”.

This book comprises eight chapters directed towards the purpose of being a special genus monograph of its typical characteristics of Chinese endemic genera, i.e. the genus centering in China that is remarkably distributed throughout much of eastern Asia. From just south of the Equator in

the tropics, to cold temperate regions as far north as latitude 50°N, the distribution pattern is relatively common among endemic higher plants in China, representing a constituent of both the Holarctic and Paleotropic floras. The book provides thorough information and detailed data of evolutionary origin, systematics and taxonomy, species description and characteristics, natural distribution and natural reserve, domestication and cultivation history, genetic variation and breeding improvement, cultivars and kiwifruit industry, etc. I have purposely shortened cultivation and industry aspects of common fruit tree books. I had helped and coauthored with the late famous kiwifruit expert Mr Cui Zhixue for his chief edited book “*Actinidia* in China” published in 2002 and it is still largely regarded as the “bible” of genus *Actinidia* by many young researchers. But due to lack of information and data integrity, I felt it has not been regarded as a world class monograph for genus *Actinidia*. Publication of Genus *Actinidia*, a world monograph has fulfilled my long efforts and aspiration in this regards and I hope the monograph will provide overall and comprehensive information and data for kiwifruit researchers and botanists in the world.

HUANG Hongwen

in Guangzhou, China, March 28, 2014

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We would like to thank Dr A.R. Ferguson, a world authority of kiwifruit, who has devoted many months to editing the book thoroughly in English and has provided most valuable advice, suggestions and outstandingly thorough checking of data, information and facts used in the text. He has also provided some photographs. His help has improved our book and we are most grateful.

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Introduction

In China, the genus *Actinidia* Lindl. is known by the name mihoutao (macaque monkey peach). Throughout the rest of the world, the most widely used commercial name is kiwifruit. The process of domestication of the kiwifruit started at the beginning of last century, little more than one hundred years ago. The fruit has been widely accepted because of its unique flavor, its high content of vitamin C, dietary fiber, and a variety of mineral nutrients, and for its beneficial effects on human health owing, for example, to its high content of antioxidants and its alleviation of gastrointestinal illnesses. Domestication and commercial cultivation of kiwifruit is considered to be one of the most spectacular examples of successful plant domestication in the 20th century.

Since the first commercial kiwifruit orchard was established in New Zealand by the 1930s, following the first introduction of *Actinidia chinensis* var. *deliciosa* into New Zealand in 1904 (Ferguson and Bollard, 1990), kiwifruit plantings and production have increased, especially since the late 1970s when commercial production spread throughout over the world. Today worldwide kiwifruit plantings have reached more than 165,000 hectares (412,500 acres) and annual production of 2 million tons (Belrose Inc. 2013).

Over the past 30 years, China has carried out extensive surveys of the natural resources of the genus *Actinidia* and has initiated many studies in taxonomy and systematics, biogeographical distribution, species and genetic diversity and habitat ecosystems, etc. The exploration of natural germplasm resources and, more recently, breeding programs have resulted in the release of many new cultivars to support the development of the kiwifruit industry. Simultaneously, the kiwifruit industry in China has developed rapidly, from essentially nothing in 1978 to current plantings and annual production accounting for about 45% and 25% respectively of the world total. China has the richest natural resources of kiwifruit and now it also produces more kiwifruit commercially than any other country. There is no doubt that China will continue to play an increasingly important role in the conservation and sustainable use of *Actinidia* natural resources as well as becoming a more important player in the world kiwifruit industry in the future.

Taxonomy, Distribution and Germplasm Resources

The genus *Actinidia* belongs to the family Actinidiaceae. According to the latest revision (Li et al. 2007), the genus has 54 species and 21 varieties, a total of about 75 taxa. Current commercial cultivation is almost entirely based on *A. chinensis* var. *chinensis* and *A. chinensis* var. *deliciosa* (A. Chevalier) A. Chevalier.

Since Lindley (1835) erected the genus, it has undergone four major revisions: Dunn (1911), Li (1952), Liang (1984) and Li et al. (2007). Early accounts of the genus separated it into four sections, *Leiocarpae* (subsequently split into two series *Lamellatae* and *Solidae*), *Maculatae*, *Stellatae* (subsequently split into two series *Perfectae* and *Imperfectae*) and *Strigosae*. However, these attempt to subdivide the genus were not satisfactory because individual species are often variable, are not readily separated and the characters used to subdivide the genus were themselves not always consistent (Huang and Ferguson, 2007a). Furthermore, many new taxa were discovered during the national survey of wild Chinese resources and extensive genetic studies of natural populations made it obvious that rather imprecise traits, such as degree of hairiness, lamellation of stem pith and fruit shape are not good criteria for classification. In particular, the treatment of the Section *Strigosae* was unsatisfactory. Before the revision of Li et al. (2007), 76 *Actinidia* species and 50 sub-specific taxa had been described (Huang and Ferguson, 2007a), resulting in considerable confusion. More recent studies by cluster analysis using both morphological traits and molecular markers have shown that either dendrogram tree or strict consensus tree analysis of phylogenetic relationships tends to group most species into geographic or regional groupings of northern China, the Yangtze River region, southern China, southeast China and southwest China. The revision by Li et al. (2007) of *Actinidia* ignored sectional groupings and clarified the status of some poorly described taxa, even if further revision is probably required: in total, 17 species, 33 varieties and 4 forms were combined or treated as synonyms by Li et al. (2007).

The genus *Actinidia* has a remarkably wide geographic

distribution in eastern Asia, extending from the equator (tropics) to cold temperate regions as far north as latitude 50° (Liang, 1983; Ferguson, 1990a). Such a distribution pattern is relatively unusual amongst higher plants, and it means that *Actinidia* is a component of the Holarctic flora as well as the Paleotropic flora. However, this pattern is typical of many Chinese endemic plant genera, i.e., centered in mainland China but extending to the neighboring countries. Two *Actinidia* species occur only in adjacent countries (*A. strigosa* Hook. f. et Thoms. in Nepal, *A. hypoleuca* Nakai in Japan) and a small number of *Actinidia* taxa are found in other countries as well as China. However, the vast majority of *Actinidia* taxa are endemic to China. There, they occur mostly in the mountains and hills of south central and southwest China with the QinLing Mountains forming a northern boundary and the HengDuan Mountains forming a western boundary. From a biogeographical viewpoint, the distribution pattern is generally from southwest to northeast China, structured into six biogeographical regions:

- southwest China (including Yunnan, Guizhou, Sichuan, western and southern Tibet);
- southern China (including Guangdong, Hainan, Guangxi and southern Hunan);
- central China (including Hubei and eastern Sichuan, Chongqing, western Hunan, southern and southwestern Henan, southern Gansu, Anhui and southern Shaanxi);
- eastern and south eastern China (including Jiangsu, Zhejiang, Jiangxi, Fujian and Taiwan);
- northern China (Hebei, Shandong, Shanxi, Beijing and Tianjin);
- northeastern China (Liaoning, Jilin and Heilongjiang).

Wild kiwifruit are very abundant. In a survey of wild kiwifruit in the early 1980s, more than 160,000 tons of fruit were collected from the wild each year.

A Century of Kiwifruit Domestication and Industry Development

Although China is the center of origin of the genus *Actinidia* and it is the richest in natural *Actinidia* resources, few serious attempts at domestication of the genus were made until it had been successfully domesticated outside China. According to ancient texts sporadic attempts had been made. Xin (1983) identified the “Chang Chu” recorded more than 2000 years ago in the *Shijing* (A Book, written between 1000 and 500 BC) as *Actinidia*, described as “growing in moist places”. A more convincing account in ancient texts is found in a poem by Cen Shen (714–770 CE) of the Tang Dynasty, the poem—*Taibai Dongxi Zhang Laoshe Notes* that is sent to his niece describes “In middle of garden, an *Actinidia* plant climbing on an arbor over a well”, suggesting as early as 1200 years ago, an *Actinidia* vine had been planted in courtyard. All the various Bencao

(great pharmacopoeias or encyclopedias) in subsequent dynasties recorded edible and medicinal uses of *Actinidia* plants and fruit. There were even occasional attempts, 200 years ago, by farmers in Huangyan County, Zhejiang Province to collect *Actinidia* plants from the wild and plant them around their homes (Cui, 1993).

The process of kiwifruit domestication and commercial cultivation started in New Zealand in 1904 when a New Zealand school teacher, Isabel Fraser, visiting Yichang (Ichang), Hubei Province, obtained seed of *A. chinensis* var. *deliciosa* and took them back to New Zealand. These seed were given to the Thomas Allison who then passed to his brother Alexander Allison, an amateur horticulturist. Plants from these original seed were fruiting by 1910. These were was probably the first fruit of *A. chinensis* var. *deliciosa* to be produced outside China. Many European naturalists and plant hunters introduced *Actinidia* from China into Europe and North America countries during the late 19th and early 20th centuries, but all subsequent important New Zealand cultivars of *A. chinensis* var. *deliciosa* including ‘Hayward’, ‘Bruno’, ‘Allison’, ‘Monty’, ‘Abbott’ and ‘Gracie’ can be traced back to those seed introduced by Isabel Fraser (Ferguson, 1983; Ferguson and Bollard, 1990; Ferguson 2004, 2005). Indeed, these early selected cultivars from New Zealand dominated world commercial kiwifruit production for more than 70 years until the mid-1980s when a number of new cultivars of both *A. chinensis* var. *chinensis* and *A. chinensis* var. *deliciosa* were selected and released for orchard production as the result of national survey of *Actinidia* resources and cultivar development organized by the Chinese Ministry of Agriculture. This resulted in noteworthy changes in the types of kiwifruit cultivars grown, which significantly changed the world kiwifruit cultivar structure.

Historical Glance of *Actinidia chinensis* Taken Outside China

At the beginning of the 20th century, China was a semi-feudal society ruled by the decaying Qing Dynasty. Many western plant hunters and collectors were therefore able to exploit China’s unique and remarkably rich flora, taking in particular ornamental and garden plants and economic plants.

The First Botanical Specimens

The earliest known *A. chinensis* specimens, currently held in French Natural History Museum, Paris, were collected by d’Incarville in 1740, but examined only 150 years later (Franchet, 1882). The description of the species (Planchon, 1847) was instead based on male flowering specimens collected by Fortune probably near Ningbo city, China in 1845 (Ferguson, 1990). The first fruiting specimens to be described were collected near Yichang, Hubei Province by the plant collector Augustine Henry (1857–1930) in 1886, and sent to the Royal Botanic

Gardens, at Kew, United Kingdom. These fruit were used to prepare the first European illustration of *A. chinensis* published by the then well-known botanist Daniel Oliver (1830–1916) (Oliver, 1887). These first specimens from Fortune and Henry were of what we now know as *A. chinensis* var. *chinensis*.

The First Living Plants of *A. chinensis* Outside China

The earliest known living plant of *A. chinensis* grown outside China was probably that recorded as being in the arboretum of Maurice de Vilmorin at Les Basrres, Loiret, France in 1899 (Vilmorin and Bois, 1904). The seed from which the plant was raised was probably collected in Sichuan in 1898 by the French missionary Père Farges. Because of its geographic origin, it is likely that this plant belonged to what is now known as *A. chinensis* var. *deliciosa*.

However, credit for the effective introduction and domestication of kiwifruit should be largely given to the well known British plant hunter Ernest Wilson (Ernest H. Wilson, 1876–1930). In his four adventurous plant collecting expeditions during 1899–1911, Wilson explored the flora of western China and collected a great number of Chinese plants, particularly ornamental plants, and sent them to nurseries (mainly James Veitch & Sons, Ltd) and botanical research institutions in the United Kingdom and the United States of America. The plants he introduced included *Actinidia chinensis*, *Davidia involucreata*, *Meconopsis integrifolia*, *Rosa moyesii*, *Clematis armandii*, *Clematis montana* var. *rubens*, and species of *Cotoneaster*, *Primula*, *Acer*, *Rhododendron*, *Viburnum*, *Hypericum*, *Lonicera*, *Berberis*, *Spiraea*, *Ceratostigma*, *Daphne*, *Deutzia*, *Exochorda*, *Dipelta*, *Forsythia*, *Kolkwitzia*, *Philadelphus*, *Syringa*, *Magnolia*, etc, as well as 65,000 plant specimens for herbaria in Western countries (Hillier, 1976; Briggs, 1993). More than 100 genera and more than 1000 species from China enriched the gardens of Europe and North America and were subsequently used in program of ornamental flower breeding and development.

1900: Wilson shipped *A. chinensis* seed to the United Kingdom, and subsequently in 1903 a plant of *A. chinensis* was exhibited at a show of the UK Royal Horticultural Society. Photographs in the Veitch catalogue the following year indicate that the plant belonged to *A. chinensis* var. *deliciosa* (Veitch, James & Sons, Ltd, 1904).

1904: A New Zealand school teacher, Isabel Fraser, on a trip to her sister, Katie Fraser, who was working in the Church of Scotland mission in Yichang, directly or indirectly obtained *A. chinensis* var. *deliciosa* seed from Wilson. When Isabel Fraser returned to New Zealand in January 1904, she took with her these seed (Atkins, 1948), seed that were the origin of the world's kiwifruit industry. The cultivar 'Hayward', still accounting for more than 80%

of the total world area planted in kiwifruit, the widely grown cultivar 'Bruno' and other early cultivars such as 'Allison', etc, are the direct descendants of those seed (Ferguson and Bollard 1990).

In July, 1904, the Plant Introduction Experiment Station at Chico, California of the U.S. Department of Agriculture (USDA) received through Hankow (Wuhan) plants of *A. chinensis* "obtained on the borders of Yunnan by Mr. Wilson" (Fairchild, 1913). Two, "possibly distinct", plants were registered as USDA Plant Introductions, Number P.I. 11629 and P.I. 11630 (USDA 1907). Subsequent photographs of the plant P.I. No. 11629 indicate that it was *A. chinensis* var. *deliciosa*.

Brief History of the Development of the Kiwifruit Industry

1904–1924: Introduction of *A. chinensis* var. *deliciosa* to New Zealand. Plants were mostly sold or exchanged between nurserymen and amateur plant enthusiasts as gifts. By 1917, New Zealand nurseries were offering to the public seedlings of *A. chinensis* var. *deliciosa* and by 1924 the new plant was being widely promoted and provoking increasing interest.

1922–1926: Grafted plants became available for sale. All members of the genus *Actinidia* are functionally dioecious and pollination by a male vine is required for fruit production. During in the early domestication period, growers were initially puzzled as to why a female plant with apparently perfect flowers did not produce fruit. Eventually it was realized that the female, apparently perfect, flowers did not produce viable pollen. Male and female plants could not at that stage be distinguished morphologically, but once they had flowered and their gender determined, grafting onto seedling rootstocks became the standard practice. This is still the usual practice in New Zealand but in other countries, vegetative propagation by cuttings or tissue culture has become widespread.

1930s: Establishment of the first commercial *Actinidia* orchard. Augustine Henry (1893) seems to have been the first to recommend cultivation. His prophetic comment was, "This fruit might be much improved by cultivation.". The United States Department of Agriculture also quoted Frank Meyer as suggesting the possibility of commercial kiwifruit orchards (USDA, 1922). However, the first *A. chinensis* var. *deliciosa* orchard actually established was that in Wanganui, New Zealand: initially only 14 plants were grown but they were producing good quality fruit by the early 1930s. Fruit were soon sent to other towns of New Zealand and readily sold. More planting followed in other parts of New Zealand, particularly in the Bay of Plenty. However, these earliest kiwifruit orchards were very small, generally less than 1 ha.

1950s: For many years, cultivation remained on a

small scale although good prices for the fruit encouraged planting by growers and the associated development of growing and management techniques and postharvest storage procedures (Ferguson, 2011). As production was beginning to exceed local consumption, trial shipments of the fruit were sent to Britain in 1952 and Australia in 1954. Exports increased steadily, in 1952, only 40 boxes were shipped to Britain, in 1954, 563 boxes and in 1960 18,700 boxes.

1959: Early western botanists and plant explorers often commented that the flavor of kiwifruit was reminiscent of the European gooseberry, *Ribes uva-crispi* (syn. *R. grossularia*). *A. chinensis* var. *deliciosa* was at one stage given the name “Ichang gooseberry” after the town of Yichang where E.H. Wilson over-wintered, but this name was seldom used and in New Zealand the plant was known as the “Chinese gooseberry” as early as 1917. This remained the most usual common name until New Zealand fruit were first exported to the United States in 1959. The exporting firm Turners & Growers then proposed the name “kiwifruit” after the kiwi, a native bird emblematic of New Zealand (Ferguson and Bollard, 1990). The new name was widely promoted in western markets, and it soon became accepted both commercially and in the scientific literature. Ironically, for many years since, people have mistakenly believed that this new emerging fruit originated from New Zealand, rather than from China.

1960–1970s: Kiwifruit commercial production in New Zealand up to the early 1970s was mainly to meet the requirements of the domestic market, but after 1975 exports began rapidly to exceed local consumption and by 1980 more than 80% of the fruit production was exported. The increasing demand resulted in a rapid expansion of plantings and more intensive management accompanied by technological improvements.

1) Standardization of cultivars and predominance of ‘Hayward’: the New Zealand kiwifruit industry was based on the introduction from China of a small number of seed of *A. chinensis* var. *deliciosa*. Initially plants were propagated by seed, but associated with propagation by grafting was the selection of good-fruited types during the 1920s and 1930s. These types with large fruit, good taste and other commercial values include what are now known as the cultivars ‘Hayward’, ‘Bruno’, ‘Allison’, ‘Monty’ and ‘Abbott’ although they were often known by a number of different names and not clearly identified as such. Comparative studies by the New Zealand Department of Scientific and Industrial Research (DSIR) resulted in recognition of some better types. A number of these were grown commercially. In 1966, the cultivar ‘Abbott’ accounted for c. 50% of total kiwifruit plantings, ‘Hayward’ for 25%, ‘Bruno’ for 20% and ‘Monty’ for c. 5% (Ferguson and Bollard, 1990). However, as exports increased it was found that fruit of ‘Hayward’ survived the prolonged transport by ship to Europe much better than fruit of the other kiwifruit cultivars then

available. As exports became more and more important, growers accepted that it was fruit quality and consumer satisfaction that were most important and ‘Hayward’ with its large, good-flavored fruit with a remarkable storage life replaced the other cultivars. By 1968, ‘Hayward’ accounted for half the kiwifruit plantings, in 1973 95% and in 1985, 98.5% (Ferguson and Bollard, 1990). By then, only ‘Hayward’ fruit were accepted for export from New Zealand, and when other countries started growing kiwifruit, they too grew ‘Hayward’. For the next 20 years, the kiwifruit industry throughout the world, with the exception of China, relied on ‘Hayward’ as its sole fruiting cultivar.

2) Improvement of orchard management techniques: ‘Hayward’ is more difficult to manage and crop than some of the other kiwifruit cultivars. Reliance on ‘Hayward’ meant that management techniques had to be modified to suit its requirements. For example, after many years of research, kiwifruit scientists and growers in New Zealand understood that for a dioecious plant such as kiwifruit, adequate pollination is critically important for achieving high yields of large, uniform fruit. As ‘Hayward’ became the only fruiting cultivar grown, the selection of matching male pollenisers became critical. Two of the first two males selected were ‘Matua’ and ‘Tomuri’ but later ‘Chieftain’ was widely planted. In addition, beehives were regularly brought into orchards. Specialized companies providing beehives to ensure kiwifruit pollination became established in kiwifruit growing areas.

3) Harvesting, packing, storage and international transportation: the successful expansion of the New Zealand export industry was possible only because of an emphasis on quality control and the standardization of harvesting, packing and storage. The development of appropriate measures of harvest maturity and of conditions for long-term storage (0°C) were particularly important (Ferguson and Bollard, 1990; Zespri, 1997; Ferguson, 2011).

1970–2012: Rise of worldwide kiwifruit industry. Commercial planting of kiwifruit started in other countries, including the United States about 1960 with the first commercial crops in 1965, Italy in 1966, France in 1967 and Japan around 1977 (Ferguson and Bollard, 1980). Commercial production further expanded to Chile in South America and Iran in Middle East during the 1980s. Meanwhile, the Chinese kiwifruit industry developed from nothing to the world’s largest over the past 30 years. In 2012, it is estimated that total kiwifruit plantings in China were c. 75,000 ha, whereas Italy had c. 27,000 ha, New Zealand c. 14,000 ha and Chile 12,000 ha (Belrose, 2013). China therefore had just over half of the total world plantings of kiwifruit, accounting for about one quarter of total world production. As young orchards mature, the proportion of kiwifruit produced in China can be expected to increase.