

The 2019 Banks Memorial Lecture: The domestication and successful commercialisation of kiwifruit

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Abstract: The history of the green-fleshed kiwifruit (*Actinidia chinensis* var. *deliciosa*) is a classic example of the successful domestication and commercialisation of a new fruit plant. Almost every step from wild plant in China to successful export crop in New Zealand is known in detail. The initial steps involved plant explorers such as Robert Fortune and E.H. Wilson. The development of kiwifruit as a commercial crop was due to enthusiastic orchardists and nurserymen, especially the selection of a good cultivar by Hayward Wright. The subsequent development of kiwifruit as a new export crop was due to the efforts of orchardists, scientists and the marketing organisations. New Zealand led the way in commercialisation of the green kiwifruit and then initiated international trade in yellow-fleshed kiwifruit (*Actinidia chinensis* var. *chinensis*). When disaster struck recently with the arrival of a new disease, bacterial blight of kiwifruit, caused by *Pseudomonas syringae* pv. *actinidiae*, it was the collaboration between scientists and the industry that resulted in the successful replacement of a cultivar susceptible to the disease with one that was more resistant. Science was able to produce tangible economic returns.

Sir Joseph Banks, Bart. KB PRS

The Banks Memorial Lecture commemorates Sir Joseph Banks (Fig. 1). In New Zealand, Banks is remembered mainly for his botanical work when, aged only 25, he joined Cook on his first voyage to the South Pacific (Ferguson, 2008). After nearly three years, the *Endeavour* returned to England with a vast collection of specimens. The plant specimens alone increased the flora of the world known to European botanists by about

a quarter: the plants were found to belong to 110 new genera and 1300 new species at a time when Linnaeus had listed only 1098 genera and about 5900 species.



Fig. 1 Sir Joseph Banks. Lithograph by William Daniell, 1811, after George Dance, 1803. Private collection.

Banks planned a series of volumes to document the scientific findings of the *Endeavour* voyage. One such volume was to be *Primitiæ Floræ Novæ Zelandiæ* (Beginnings of a New Zealand flora), which should have been a splendid start to the European scientific study of the New Zealand flora. Despite the preparation of diagnoses of 349 New Zealand plants by Solander, together with engravings of more than 180 plants, the work was never published.

This was partly because Banks had so many other interests and so many other duties, such as being President of the Royal Society of London for more than forty years, de facto chief scientific adviser to the British Government and adviser to George III on the Royal Botanic

Gardens at Kew. He organised many expeditions to collect plants for Kew from different parts of the world (Ferguson, 2008). He encouraged and facilitated transfer of economically important plants from one part of the world to another, such as the transfer of breadfruit (*Artocarpus altilis*) from Tahiti to the West Indies, a great achievement as an exercise in plant transfer on a grand scale (Mackay, 1974), even if, regrettably, the slaves in the West Indies found the fruit unpalatable. Banks believed that scientific discoveries had the potential to produce economic advantages. He was an imperialist in that he hoped that such discoveries would be made by his fellow countrymen, ultimately for the benefit of the British Empire, rather than by the inhabitants of other countries.

Domestication of kiwifruit

I like to think that Banks would be pleased by the story of the kiwifruit's success, the evolution from being a wild plant in China to an important crop at the other end of the world; that he would be impressed by the economic benefits that domestication of the kiwifruit has brought, particularly to New Zealand. After all, Banks was keen to promote agriculture and horticulture, he was much involved with the introduction of Chinese plants to Kew, and he encouraged travellers to China to be aware of the potential of Chinese plants. He gave advice to the embassy of Lord Macartney to China in 1793, writing a long document, *Hints on the Subject of Gardening suggested to the Gentlemen who attend the Embassy to China*, and supplied a list of the Chinese plants, largely based on observations of Jesuit missionaries, that he was particularly keen to obtain (Kitson, 2013).

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The origins of most crop plants are a matter for speculation: the progenitors of the cultivated plant can often be deduced but the process and timing of domestication usually remains conjectural. Only in a few exceptional cases have the various stages of domestication – recognition, introduction, cultivation, selection, commercialisation, and promotion – been identified in detail. Kiwifruit are one such exception.

Kiwifruit belong to the genus *Actinidia*, a genus of some 50 species centred in southern China. The name “kiwifruit” was devised in 1959 by Turners & Growers of New Zealand with the first exports of the fruit to the United States of America (Stead, 1997). Originally it was applied to the fruit of *A. chinensis* var. *deliciosa*. Now the name is also commonly used for fruit of *A. chinensis* var. *chinensis*. These two varieties of *Actinidia chinensis* differ most obviously in the hairiness of their fruit: those of *A. chinensis* var. *chinensis* typically have pale, short soft hairs, like the fuzz of a peach, whereas fruit of *A. chinensis* var. *deliciosa* have brown, hispid hairs that are like bristles (Fig. 2). Furthermore, the fruit flesh of the variety *chinensis* is usually, although not always, golden yellow, whereas that of the variety *deliciosa* is almost always green. The two varieties have sometimes been treated as separate species (Liang and Ferguson, 1986) but Li et al. (2007) in their revision of the genus *Actinidia* concluded that these two taxa are better treated as varieties of the one species rather than as distinct species: hence the reduction in rank of *A. deliciosa* to a variety of *A. chinensis*. The two varieties come from different parts of China: var. *chinensis* from more eastern, warmer regions at lower altitudes, var. *deliciosa* from more western, colder, higher-altitude regions. Consequently, the responses of the two varieties on cultivation under specific climatic conditions tend to differ.

The pathways of domestication of the two varieties are very different. The type specimen of the species belongs to what is now *A. chinensis* var. *chinensis* (Planchon, 1847) and the first illustrations of the species in European literature (Oliver, 1887) are also of this variety. However,

most of the introductions and the only successful ones at the beginning of the 20th century from China to New Zealand, the United Kingdom and the United States of America were of *A. chinensis* var. *deliciosa* (Ferguson and Bollard, 1990; Ferguson, 2004; Huang, 2014).



Fig. 2 Fruit of *Actinidia chinensis* var. *chinensis* (left) have a fine tomentum whereas fruit of *A. chinensis* var. *deliciosa* (right) are covered in stiff hairs. Photo: © Plant & Food Research.

Almost every step in the progression of this variety from wild plant to an important crop in New Zealand, in the early years of last century, is known and has been documented (Ferguson and Bollard, 1990). The success of the local industry led, in turn, to the widespread planting of kiwifruit elsewhere in the world. It is a uniquely New Zealand success story, a success that is due to the efforts of nurserymen, good growers, advisory officers, scientists and a unified industry that is market driven.

The kiwifruit industry that developed in New Zealand and then spread to other countries was thus based on the green-fleshed kiwifruit, *A. chinensis* var. *deliciosa*. The first commercial kiwifruit plantings of this variety in China, the country of origin, came much later, in 1979/1980 near Chibi in south-eastern Hubei using a cultivar, ‘Hayward’, selected in New Zealand (J.-B. Fang, pers. comm.). This was at least 50 years after the establishment of the very first commercial orchard of var. *deliciosa* in New Zealand.

Botanical recognition of *Actinidia chinensis*

Although kiwifruit were described in a number of Chinese pharmacopoeia and texts, it seems that before the mid-20th century there was no attempt in China at systematic cultivation. Instead, the fruit were collected from the wild (Ferguson, 1990; Huang, 2014). Kiwifruit in China were simply wild plants and remained so for many years.

The first botanical studies on kiwifruit were the result of the European explorations of the richness of the Chinese flora, much richer than those of other comparable areas in the world. Sir Joseph Banks had been present at the inaugural meeting in 1804 that resulted in the formation of the Horticultural Society, later the Royal Horticultural Society. The Horticultural Society was keen to acquire new plants from China, plants that would be suitable for the temperate climate of Europe. In 1843 the Society sent Robert Fortune to China as a plant collector with very detailed guidelines as to likely plants of interest and the instruction, “You will also prepare for the Society one set of dried specimens of all plants that you may meet with ...” (Cox, 1945). Accordingly, he collected the type specimen of *Actinidia chinensis*, of a male plant, near Ningbo in China, probably in May 1845. This was formally described two years later by Jules Émile Planchon and is of what is now called *A. chinensis* var. *chinensis*. (Specimens of *A. chinensis* had been collected earlier in 1740 by the French Jesuit Pierre d’Incarville but remained undescribed in Paris for nearly 150 years.)

It seems unlikely that Fortune ever saw the fruit (Ferguson and Bollard, 1990). The first fruit of the new species to be seen in Europe, also of var. *chinensis*, were collected by Augustine Henry and sent to Kew. These were illustrated in the first European description of the fruit (Oliver, 1887). In his writings, Henry commented several times on the excellent potential of the fruit.

Dr Henry was a customs officer at Ichang (now Yichang) just downstream from the entrance to the Yangzi Gorges. Henry was one of the greatest plant collectors of all time, sending 158,000 herbarium

specimens to Kew, in all 6000 distinct species of which nearly 1000 species, 30 genera and one family were previously botanically undescribed (Ferguson, 1986). The wealth of garden-worthy plants revealed enticed James Veitch and Sons Ltd, the great London nursery firm, to send Ernest Wilson (Fig. 3) to China to collect plants suitable for the nursery trade. He started his first trip to China in 1899.



Fig. 3 E.H. Wilson, plant explorer, at the time of his first trip to China. Photograph from *The Gardeners' Chronicle* 3rd Series 37 (1905): 114.

Introduction of *Actinidia chinensis*

Botanists and plant collectors such as Wilson soon realised that there was considerable variation in the fruit of *Actinidia chinensis*, the variation being most obvious in the hairiness of the fruit skin (Ferguson, 2004). This variation was not, however, formally recognised until the description by Chevalier (1940, 1941) of the variety *A. chinensis* var. *deliciosa*.

In 1899 and in the early years of the 20th century seed and, in some cases, plants of *A. chinensis* were sent to France, the United Kingdom, the United States of America and New Zealand (Ferguson and Bollard, 1990; Ferguson, 2004). Some introductions were of *A. chinensis* var. *chinensis*, particularly to the United States, but these all seem to have been unsuccessful. For example, the United States Department of Agriculture distributed plants derived from seed of what were probably two accessions of var. *chinensis* to nearly 700 locations (Huang, 2014), but there is no indication that any of these plants flowered, fruited or even survived.

Most attempts to introduce *A. chinensis* var. *deliciosa*, mainly through Wilson, were only marginally more successful. In Europe and the United States, var. *deliciosa* was to remain for many years an ornamental curiosity rather than a potential fruit crop. Only in New Zealand was the introduction of var. *deliciosa*, the green-fleshed kiwifruit, really successful in that it led to the development of a new fruit crop (Ferguson, 2005).

Wilson frequently made Yichang his base for collecting trips in China and he overwintered there. Yichang was a busy port and a starting point for travels into western China. Wilson (1913) writing subsequently on *A. chinensis* related: "In 1900 I had the pleasure of introducing this fruit to the foreign residents of Ichang, with whom it found immediate favour, and it is now known through the Yangtze Valley as the Ichang gooseberry." At that stage there were only about 45 European residents in Yichang and Wilson would probably have been known to all of them (Ferguson, 2004). Amongst the European residents was a woman missionary from New Zealand, Katie Fraser.

In 1903, Katie Fraser's sister, Isabel Fraser (Fig. 4), visited her in Ichang and when Isabel returned to New Zealand in February 1904 she took with her seed of *A. chinensis* var. *deliciosa* (Atkins, 1948). It is very likely that these seed came directly or indirectly from Wilson.



Fig. 4 Isabel Fraser who brought kiwifruit seed to New Zealand, 1904. Photograph from *The Adastrian* (1910). Whanganui Regional Museum.

Successful establishment of *Actinidia chinensis* var. *deliciosa* in New Zealand

The seed introduced were given to a Wanganui farmer, Alexander Allison. He was lucky in that the seed produced male and female plants, the climate of Wanganui was suitable and it is recorded that by 1910 he was producing fruit, that were, as far as we know, the very first *A. chinensis* fruit produced outside China (Ferguson, 2004, 2005). Plants were soon exchanged or sold to fellow horticultural enthusiasts and by 1917 plants were being sold to the public. Commercial production of kiwifruit soon followed, with first an orchard of some 14 vines being established at Wanganui in the late 1920s followed by a larger orchard of about 60 vines. Fruit were being sold to the public by the mid-1930s with reportedly, "... the demand exceeding the supply" (Whelan, 1935). Already, the commercial prospects looked favourable: "As the fruit becomes better known the demand will increase, so that in a few years it should play an important part in the fruit produce of New Zealand" (Rice, 1936). Prices were good and growers made money.

Selection of superior strains and the introduction of the cultivar 'Hayward'

All members of the genus *Actinidia* are dioecious; that is, male and female flowers are on separate plants. The first kiwifruit plants in New Zealand were raised from seed and many growers ended up with plants of only one sex and therefore no fruit. At that date it was not possible to distinguish male from female plants and some nurseries advised growing at least half-a-dozen seedlings to ensure, it was hoped, at least one plant of each sex. Kiwifruit are large and vigorous plants requiring strong and expensive support structures. Growing half-a-dozen vines in quite a commitment. The obvious solution was instead to sell grafted plants of known sex and these were available by the early 1920s (Ferguson and Bollard, 1990). As existing plants had been raised from seed there was great variation in the fruit and it was recommended that "... any further plantings for commercial purposes should be of the large oval, or elongated, green-fleshed type, with an entire absence

of internal fibrous or woody material” (Sydenham, 1944). The most notable of such superior selections could all be traced back to two female plants and one male plant, themselves coming from the original plants of Alexander Allison. This was a very narrow genetic base for an expanding crop.

Hayward Wright (Fig. 5), a nurseryman of Avondale, Auckland, selected a good-fruited type which he called ‘Wright’s Large Oval’ (Ferguson, 1983), later to be named after him as ‘Hayward’ (Mouat, 1958; Fig. 6). This had large fruit with good flavour and a remarkable storage life. The first commercial planting of ‘Hayward’ was established near Auckland in the late 1930s and in the Bay of Plenty in the early 1950s (Ferguson and Bollard, 1990). ‘Hayward’ fruit were first exported in 1959 and quickly proved their marked superiority, arriving in export markets in much better condition than fruit of some of the other kiwifruit cultivars then grown. ‘Hayward’ was not the most productive or the easiest cultivar to grow (Mouat 1958; Ford, 1971) but it was eventually realised and then accepted by growers and exporters that to keep overseas customers and consumers satisfied, ‘Hayward’ should be the only kiwifruit exported. “... it was not until the advent of the Hayward variety that any appreciable progress in overseas marketing was noticeable ... Haywards will soon be the key variety both for the local market and for export. The future potential lies in Hayward” (Conway, 1967).

Plantings of ‘Hayward’ expanded rapidly: in 1965, only 25% of New Zealand kiwifruit orchards were planted in ‘Hayward’; by 1969, 70% of all orchards, in 1973, 95% of all orchards, and in 1975 only ‘Hayward’ fruit were being accepted for export. The successful development of kiwifruit as a commercial crop is largely due to this reliance on ‘Hayward’ (Ferguson, 2011) particularly as cool-storage trials (Padfield and Bridgman, 1950; Padfield and Bailey, 1952) had established that kiwifruit could be stored for long periods at 0°C if harvested at the right maturity, and that they could be sent by refrigerated ship to the other side of the world and arrive in good condition.

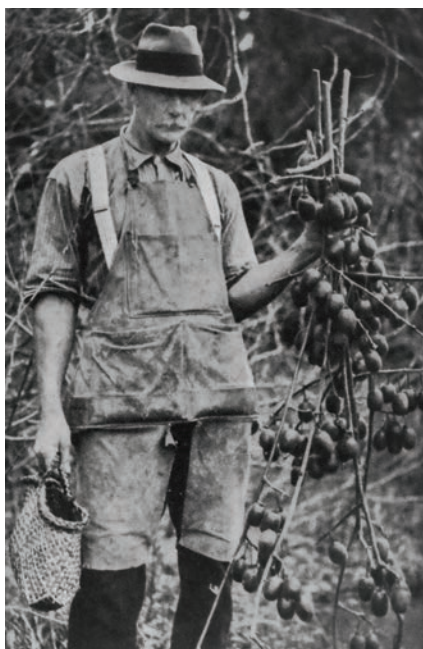


Fig. 5 Hayward Wright who selected the kiwifruit cultivar ‘Hayward’. Photograph from *The New Zealand Smallholder* 12 (1930): 276.



Fig. 6 *Actinidia chinensis* var. *deliciosa* ‘Hayward’. Photo: © Plant & Food Research.

Other countries, encouraged by the success of the New Zealand industry, started to grow kiwifruit and, not surprisingly, they adopted the cultivar that had been chosen in New Zealand. For the last 25 years of the 20th century, ‘Hayward’ was therefore essentially the only kiwifruit of international trade. It was THE kiwifruit. In most countries producing kiwifruit, there was a monoculture of one cultivar of one botanical variety of one *Actinidia* species with accompanying polliniser males. “The kiwifruit industry is unique among global fruit industries in being so totally dominated by one variety, the Hayward. Most consumers are not even aware that other varieties exist” (Belrose Inc., 1998).

There were some advantages in the world industry being so reliant on one cultivar: management practices successfully developed in one

country could usually be adopted in other countries and there was one uniform standardised product. This was also a disadvantage as New Zealand faced increased competition in world markets, with the one uniform product also produced by its competitors. In 1970, New Zealand had been responsible for 95% of the total world production of kiwifruit but by 1997 this had fallen to only 25% and was continuing to decrease. Competition was partly met by the development of the Zespri® brand with the aim of distinguishing Zespri® kiwifruit from those of competitors and to get a higher price for Zespri® kiwifruit (Beverland, 2001). Zespri was the grower cooperative which had been established to be responsible for essentially all the marketing of New Zealand kiwifruit in overseas markets other than Australia. Each fruit exported was individually labelled. A potentially much more serious problem remained: there was the risk of disease epidemics because of the shockingly narrow genetic base on which the whole industry was based. Although the excellence of ‘Hayward’ had allowed the development of the kiwifruit industry of New Zealand based on exports, far-sighted scientists concluded that it would be an advantage for the New Zealand industry to have new, unique, protectable kiwifruit cultivars, and to increase the genetic diversity in kiwifruit orchards.

The breeding of ‘Hort16A’

Increased knowledge of the genus *Actinidia* had revealed the great genetic diversity within the genus, with variation in fruit characteristics such as infructescence number, size, shape, skin hairiness, skin palatability, external colour, internal flesh colour, texture, flavour, nutrient composition, time to maturity and storage life. The late Dr Ron Davison (Fig. 7) of the former Department of Scientific and Industrial Research recognised the potential of this diversity as well as the urgent need to expand the genetic diversity of the crop. He encouraged the collection of *Actinidia* germplasm from China and stressed the need for kiwifruit breeding programmes even though this priority was not always shared by many in the industry.

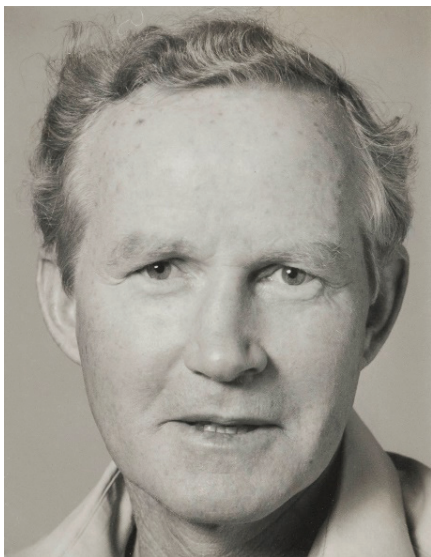


Fig. 7 Dr R.M. Davison, DSIR, promoted kiwifruit breeding programmes.
Photo: © Plant & Food Research.

Actinidia chinensis var. *chinensis* seemed to provide the most promising germplasm for the development of new kiwifruit cultivars. Many genotypes had fruit with golden-yellow flesh and a very different, sweet flavour, even if the fruit were generally small, had a short storage life and had thin, rather delicate skins that were easily damaged either on the vine or during handling after harvest.

Nearly 80 years after the start of the domestication of the green-fleshed kiwifruit around 1900 came the initial steps in the domestication of *A. chinensis* var. *chinensis* (Huang, 2014). Possibly the first-ever commercial orchard of this variety was established by the transplantation of vines from the wild to an orchard in Xixia, Henan, around 1980. Subsequent development of this variety in China was rapid, with many cultivars selected and planted by 1985 (Huang, 2014). These developments were paralleled by development of cultivars of *A. chinensis* var. *chinensis* in New Zealand. The first seed of the variety had been introduced into New Zealand in 1977 (M.A. McNeilage, pers. comm.) by the late Dr Don McKenzie, better known as an apple pomologist and breeder, and an Associate of Honour of the Royal New Zealand Institute of Horticulture.

In 1987, Dr Mark McNeilage (Fig. 8) crossed two genotypes of *A. chinensis* var. *chinensis* from different parts of China (Muggleston et al., 1998). The seedlings were planted at the Te Puke Research

Orchard and in 1991 Russell Lowe (Fig. 9) and Hinga Marsh selected one seedling from the cross for its remarkable fruit characteristics. Two years later the selection was entered into pre-commercial trials and then in 2000 the new cultivar, 'Hort16A' was launched in international markets under the marketing name ZESPRI™ GOLD Kiwifruit. It was very different from the existing 'Hayward': its skin was not hairy but covered in a fine tomentum; the flesh was a beautiful golden yellow if fruit were harvested at the right maturity; the flavour was sweeter, more "subtropical", and markedly less acidic.



Fig. 8 Dr M.A. McNeilage carried out the cross that produced 'Hort16A' marketed as ZESPRI™ GOLD Kiwifruit.
Photo: © Plant & Food Research.



Fig. 9 R.G. Lowe carried out the cross that produced 'Zesy002' marketed as Zespri® SunGold Kiwifruit.
Photo: © Plant & Food Research.

Suitable techniques had to be developed for the orchard management of the new cultivar as the requirements of the new plant were rather different from those of 'Hayward'. Procedures had to be developed for the handling and storage of the new fruit, especially as the characteristic sharp-pointed distal

end of the fruit made it susceptible to handling damage. Sustained marketing was necessary to promote this new fruit, different from the kiwifruit to which consumers had become accustomed.

The success, then death of 'Hort16A'

Most potential problems were quickly overcome. Fruit of 'Hort16A' were the first of *A. chinensis* var. *chinensis* to enter international trade. It was the first important kiwifruit cultivar to result from a deliberate, planned breeding programme. It was novel because of its flesh colour and different flavour, and it appealed greatly to customers who were prepared to pay much more than they would for the by-then established, green-fleshed 'Hayward' fruit. It gave a great stimulus to the New Zealand industry (Ferguson, 2015), especially as the orchard gate returns per hectare were usually two to three times those for 'Hayward': the vines bore heavier crops and the prices obtained for the fruit were higher. It was distinct because of its shape, and it was a protected cultivar that could be grown only under licence, either in New Zealand or overseas for complementary seasonal supplies. Production expanded rapidly. In 2000, 5 million trays of ZESPRI™ GOLD kiwifruit were exported, in 2012, 29 million trays, just over a quarter of all the kiwifruit exported from New Zealand. Zespri was now able to market two quite different types of kiwifruit: more acidic, green-fleshed *A. chinensis* var. *deliciosa* 'Hayward' and sweeter, yellow-fleshed *A. chinensis* var. *chinensis* 'Hort16A'.

'Hort16A' was driving the expansion of the New Zealand kiwifruit industry and it was confidently expected that production and sales would continue to expand rapidly. Instead, production and exports declined calamitously so that in 2016 only 2 million trays were exported and by the following year, 'Hort16A' was essentially dead as a commercial cultivar. It was killed by a virulent biovar of bacterial canker of kiwifruit (*Pseudomonas syringae* pv. *actinidiae*, Psa). This was first detected in New Zealand in November 2010 and spread rapidly, partly because of the abundance of susceptible plants near the site of the original outbreak in the Bay of Plenty (Vanneste, 2017).

The disease could affect 'Hayward' vines but, in New Zealand, generally not that seriously; it had, however, a devastating effect on 'Hort16A'. Spotting on leaves was followed by cane wilt and dieback, the formation of cankers, often oozing bacteria-filled exudates, and death within a few months (Mowat et al., 2013). Bacterial diseases of plants are notoriously difficult to control, Psa was especially virulent, and it was soon obvious that commercial production of 'Hort16A' fruit was no longer feasible.

Kiwifruit are uniquely important to the New Zealand economy. When Psa arrived, kiwifruit made up about two thirds of all fresh fruit exports, and 'Hort16A' fruit were the most profitable of kiwifruit exports. The loss of 'Hort16A' from disease is estimated to have cost possibly \$NZ900 million in lost exports, together with the loss of hundreds of jobs (Vanneste, 2017). 'Hort16A' growers were faced not only with the loss of crop but also a savage decrease in the value of their orchards.

The recovery – 'Zesy002'

The New Zealand kiwifruit industry had to learn how to successfully grow kiwifruit in a Psa environment (Zespri Group Ltd, 2013). The surprisingly rapid recovery of the industry from the Psa crisis can be ascribed to a number of causes but probably the most important was the introduction of a new cultivar with yellow-fleshed fruit, a cultivar that was much less susceptible to Psa. 'Zesy002' was the product of a kiwifruit breeding programme funded by Plant & Food Research (PFR) and Zespri. A series of planned crosses ended in a cross made by Russell Lowe of PFR in November 2000. A seedling was selected in May 2005 based on fruit weight, fruit shape and superior taste.

Initially it seemed that the main advantage of the selection was that it would widen the market window for New Zealand yellow-fleshed kiwifruit. It was expected that it would be ready for harvest up to three weeks ahead of 'Hort16A'. Early-season kiwifruit can fetch a marked premium on export markets. Much more important, however, 'Zesy002' proved to be reasonably tolerant of Psa. It had been released to growers in 2010, but the arrival of Psa that year accelerated the planned

distribution of budwood. 'Zesy002' was chosen as the replacement to 'Hort16A' and in 2012 1860 ha of 'Hort16A' orchards were grafted over to 'Zesy002'. In subsequent years licences for further plantings were approved so that by 2018 there were about 6500 ha of 'Zesy002' orchards established, nearly half of the total area in kiwifruit. The transition from 'Hort16A' to 'Zesy002' was achieved remarkably quickly. Although the flavour of the new gold fruit was very different, in some attributes 'Zesy002' was superior to 'Hort16A': the fruit were naturally larger, numbers of fruit were high without the application of dormancy breakers, and the absence of the sharp-pointed stylar end meant less fruit damage during handling and packing. 'Zesy002' fruit are marketed as Zespri® SunGold Kiwifruit.

Table 1 Exports of Zespri® SunGold Kiwifruit ('Zesy002') from New Zealand (data from Zespri Annual Reports).

Year	Trays of Zespri® SunGold Kiwifruit exported
2012	1 million
2013	7 million
2014	19 million
2015	32 million
2016	48 million
2017	52 million
2018	68 million

Exports expanded rapidly, particularly to Asia where the sweeter, less acidic flavour of the yellow-fleshed cultivars is preferred. By 2018, exports of Zespri® SunGold Kiwifruit ('Zesy002') were worth more than the exports of 'Hayward' fruit, as they fetch higher prices. This year, 2019, it is predicted that more Zespri® SunGold Kiwifruit than 'Hayward' fruit will have

been exported. The industry still has two main products, green-fleshed and yellow-fleshed kiwifruit (Fig. 10), but the former yellow-fleshed product has been completely replaced. The new yellow-fleshed kiwifruit are now Zespri's most valuable product. Many New Zealanders outside the kiwifruit industry have probably not yet realised the impact of the yellow-fleshed kiwifruit. "SunGold ['Zesy002' fruit], in particular, is a game-changing product that consumers love. SunGold is expected to drive future growth and is likely to overtake Green ['Hayward'] in its share of the total Zespri portfolio in 2018/19" (Zespri Group Ltd, 2018).

The future

The New Zealand kiwifruit industry has changed radically since the turn of the century when it had a single product: green-fleshed 'Hayward' fruit of *A. chinensis* var. *deliciosa*. There was firstly the successful commercialisation of yellow-fleshed fruit of 'Hort16A' of *A. chinensis* var. *chinensis*, then the loss of this cultivar, then its successful replacement by 'Zesy002'. Export markets have also changed, with China now being New Zealand's most important market for kiwifruit. Predicting future changes is therefore risky. It is likely that yellow-fleshed cultivars will become even more important; red-fleshed cultivars are a realistic possibility, as are sweeter green-fleshed cultivars and hermaphrodite cultivars. New Zealand orchards with two main kiwifruit cultivars are still dangerously uniform and at risk from new pests or diseases. Climatic change may render continued cultivation of



Fig. 10 Green and Gold, at present the main products of the New Zealand kiwifruit industry. Left, 'Hayward' kiwifruit and right, Zespri® SunGold Kiwifruit ('Zesy002'). Photo: © Plant & Food Research.

'Hayward' uneconomic in many of the areas of New Zealand in which it is now grown (Tait et al., 2018).

Good cultivars are necessary but not sufficient

In this account I have emphasised the importance of good cultivars to the successful development of the New Zealand kiwifruit industry. And, of course, a new fruiting cultivar usually requires the selection of new, compatible male cultivars. However, although the need for a selection to have good fruit characteristics might seem obvious, these alone are not sufficient. To become a successful commercial cultivar many other attributes are required and this involves many others than just the scientists and nurserymen responsible for plant improvement. The selection must be managed satisfactorily, it must be productive, it must be profitable for the growers, the fruit must be capable of storage for long periods and they must appeal to the consumers. It has been estimated (Martin and Luxton, 2005) that if "... the research cost including product development and cultivar selection is one, the development costs, including grower involvement in the planting or grafting, development of growing systems and resolution of technical issues are approximately three times the research cost. By far the largest cost is the planning and executing of the marketing and promotional support which will account for between 10 and 12 times the cost of the original research to develop the variety." So the success of a new cultivar depends on its promotion and marketing as well as the quality attributes of the fruit (O'Rourke, 2011). Good growers are also essential.

The New Zealand kiwifruit industry is often praised for its strong industry structures and coordinated marketing. These undoubtedly help but perhaps more important is the industry belief in innovation, that "the continued success of the New Zealand kiwifruit industry depends on how well it innovates in comparison to its competitors, creating value across the supply chain from breeding to consumer" (Zespri Group Ltd, 2017). Perhaps even more important is the over-riding emphasis on quality and consumer satisfaction (Costa et al.,

2018). Growers are encouraged by financial incentives to produce fruit of the required sizes and desired quality. Consumer satisfaction is largely determined by the sugar content of the ripe fruit at the stage at which it is eaten (Burdon et al., 2004), and this can be indicated by the fruit dry-matter content at harvest. A large proportion of the price paid to New Zealand kiwifruit growers is determined by taste parameters. High yields are not sufficient: consumers must be considered first.

This paper is dedicated to the memory of the late Dr R.M. Davison, a pioneer of kiwifruit science.

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References

- Atkins, A.M. (1948). Introduction of Chinese gooseberry. *New Zealand Gardener* 4: 795.
- Belrose Inc. (1998). World Kiwifruit Review 1998. Pullman, Belrose Inc.
- Beverland, M. (2001). Creating value through brands: the ZESPRI™ kiwi fruit case. *British Food Journal* 103: 383–399.
- Burdon, J.; McLeod, D.; Lallu, N.; Gamble, J.; Petley, M.; Gunson, A. (2004). Consumer evaluation of "Hayward" kiwifruit of different at-harvest dry matter contents. *Postharvest Biology and Technology* 34: 245–255.
- Chevalier, A. (1940). Sur des lianes fruitières intéressantes: les *Actinidia*. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 20: 10–15.
- Chevalier, A. (1941). Un *Actinidia* à fruits comestibles intéressant pour la France. (*A. chinensis* Planch. var. *deliciosa* Chev.) *Revue de Botanique Appliquée et d'Agriculture Tropicale* 21: 240–244.
- Conway, S.M. (1967). Report to the General Manager and Directors of the New Zealand Fruitgrowers' Federation Ltd on an overseas trip of S.M. Conway to United Kingdom, France, Germany, Australia, Hong Kong, Japan and North American Continent. October 10th to December 13th, 1966. [Auckland], New Zealand Fruitgrowers' Federation Ltd.
- Costa, G.; Ferguson, R.; Huang, H.; Testolin, R. (2018). Main changes in the kiwifruit industry since its introduction: present situation and future. *Acta Horticulturae* 1218: 1–16.
- Cox, E.H.M. (1945). Plant hunting in China. London, Collins.
- Ferguson, A.R. (1983). Hayward Reginald Wright: nurseryman, the importer and raiser of new fruits. *Annual Journal of the Royal New Zealand Institute of Horticulture* 11: 36–56.
- Ferguson, A.R. (1986). Augustine Henry. (Book review). *New Zealand Journal of Botany* 24: 673–675.
- Ferguson, A.R. (1990). The kiwifruit in China. pp. 155–164 + 3 plates. In: Warrington, I.J.; Weston, G.C. (eds). *Kiwifruit: Science and Management*. Auckland, Ray Richards Publisher in association with the New Zealand Society for Horticultural Science.
- Ferguson, A.R. (2004). 1904 – the year that kiwifruit (*Actinidia deliciosa*) came to New Zealand. *New Zealand Journal of Crop and Horticultural Science* 32: 3–27.
- Ferguson, A.R. (2005). Why were kiwifruit initially successful only in New Zealand? *Acta Horticulturae* 694: 223–227.
- Ferguson, A.R. (2008). The 2008 Banks Memorial Lecture: Sir Joseph Banks and the transfer of crop plants. *New Zealand Garden Journal* 11(2): 9–15.
- Ferguson, A.R. (2011). Kiwifruit: evolution of a crop. *Acta Horticulturae* 913: 31–42.
- Ferguson, A.R. (2015). Kiwifruit in the world – 2014. *Acta Horticulturae* 1096: 33–46.
- Ferguson, A.R. and Bollard, E.G. (1990). Domestication of the kiwifruit. pp. 165–246 + 3 plates. In: Warrington, I.J.; Weston, G.C. (eds). *Kiwifruit: Science and Management*. Auckland, Ray Richards Publisher in association with the New Zealand Society for Horticultural Science.
- Ford, I. (1971). Chinese gooseberries – success lies in pruning. *New Zealand Journal of Agriculture* 122(4): 43–45.
- Huang, H.-W. (2014). The genus *Actinidia*, a world monograph. Beijing, Science Press.

- Kitson, P.J. (2013). Forging Romantic China: Sino-British Cultural Exchange 1760–1840. Cambridge, Cambridge University Press.
- Li, J.-Q.; Li, X.-W.; Soejarto, D.D. (2007). Actinidiaceae. pp. 334–360. In: Wu, Z.-Y.; Raven, P.H.; Hong, D.-Y. (eds.). Flora of China, Vol. 12. Beijing, Science Press; St Louis, Missouri Botanical Garden.
- Liang, C.F. and Ferguson, A.R. (1986). The botanical nomenclature of the kiwifruit and related taxa. *New Zealand Journal of Botany* 24: 183, 184.
- Mackay, D. (1974). Banks, Bligh and breadfruit. *New Zealand Journal of History* 8: 61–77.
- Martin, R.A. and P. Luxton, P. (2005). The successful commercialisation of ZESPRI™ Gold Kiwifruit. *Acta Horticulturae* 694: 35–40.
- Mouat, H.M. (1958). New Zealand varieties of yang-tao or Chinese gooseberry in New Zealand. *New Zealand Journal of Agriculture* 97: 161, 163, 165.
- Mowat, A.; Clark, G.; Black, M.; Bengel, J.; Parkes, B.; Kay, S.; Tanner, D. (2013). Adapting to a virulent bacterial canker in kiwifruit. *Chronica Horticulturae* 53(3): 4–9.
- Mugglestone, S.; McNeilage, M.; Lowe, R.; Marsh, H. (1998). Breeding new kiwifruit cultivars: the creation of Hort16A and Tomua. *Orchardist New Zealand* 71(8): 38–40.
- Oliver, D. (1887). *Actinidia chinensis*, Planchon. *Hooker's Icones Plantarum* 16: Tab. 1593.
- O'Rourke, D. (2011). Dealing with changing world markets for kiwifruit. *Acta Horticulturae* 913: 45–49.
- Padfield, C.A.S. and Bailey, F.L. (1952). Chinese gooseberries (*Actinidia chinensis*): a survey of their behaviour in cool storage at all stages of harvest maturity from May to July. *New Zealand Journal of Science and Technology* A33(5): 113–116.
- Padfield, C.A.S. and Bridgman, M.J. (1950). Effect of temperature on Chinese gooseberries in cool store. *New Zealand Journal of Science and Technology* A31(6): 61–63.
- Planchon, J.E. (1847). Sur la nouvelle famille des Cochlospermées. *London Journal of Botany* 6: 294–311.
- Rice, W.H. (1936). *Actinidia chinensis* (Chinese gooseberry). Souvenir Magazine, The National Flower Show (New Zealand National Horticultural Week) 1936: 97–98.
- Stead, K. (1997). One hundred l'm bid. A centennial history of Turners & Growers. Auckland, Kestrel Publishing.
- Sydenham, F. (1944). Cultivation of the Chinese gooseberry. *New Zealand Journal of Agriculture* 68: 111–113.
- Tait, A.; Paul, V.; Sood, A.; Mowat, A. (2018). Potential impact of climate change on Hayward kiwifruit production viability in New Zealand. *New Zealand Journal of Crop and Horticultural Science* 46: 175–197.
- Vanneste, J.L. (2017). The scientific, economic, and social impacts of the New Zealand outbreak of bacterial canker of kiwifruit (*Pseudomonas syringae* pv. *actinidiae*). *Annual Review of Phytopathology* 55: 377–399.
- Whelan, J.W. (1935). No. 453. Chinese gooseberry (*Actinidia chinensis*). *The Guide* [Horticulture Division, Department of Agriculture, New Zealand] 4: 326–329.
- Wilson, E.H. (1913). A Naturalist in Western China with Vasculum, Camera and Gun. London, Methuen & Co, Ltd.
- Zespri Group Ltd. (2013). Annual Report 2012/2013.
- Zespri Group Ltd. (2017). Annual Report 2016/2017.
- Zespri Group Ltd. (2018). Annual Review 2017/2018.