

Joseph Bancroft's discovery of Fusarium Wilt of banana

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ABSTRACT

In the early decades of British settlement at Sydney Cove in 1788, the struggling colonials tried their hand at growing edible bananas but invariably failed. However, they grew extremely well in the Moreton Bay colony (Brisbane) and over time banana growing became an important agricultural industry there, particularly after the introduction of the Cavendish variety. All was progressing well until a new disease appeared in plantations around Brisbane in the early 1870s. The medical practitioner and naturalist Joseph Bancroft investigated the problem and concluded that a fungus was implicated as the causal agent. In the early 1900s, following serious outbreaks of a disease with similar symptoms in Caribbean countries (where it was called Panama Disease), the American bacteriologist Erwin Frink Smith studied the same disease in Cuba, and named the pathogen *Fusarium cubense*. Another American scientist, Elmer Walker Brandes, conclusively proved that *Fusarium cubense* (now called *Fusarium oxysporum* f.sp. *cubense*) was the cause of the banana disease. Bancroft's discovery of the disease now called Fusarium Wilt not only predates other reports of the disease in the Caribbean but also represents the first scientific investigation of a plant disease in Australia.

Keywords: banana, Elmer Brandes, Erwin Frink Smith, *Fusarium oxysporum* f.sp. *cubense*, fusarium wilt, Henry Tryon, Joseph Bancroft, *Musa*.

Introduction

The banana (*Musa* spp.) is an internationally important food crop, with almost 124 million t of fruit being produced every year. India has the largest production (approx. 33 million t), followed by China (11.7 million t) and Indonesia (8.7 million t). Countries whose citizens are categorised as being of lower-middle-income, and low-income with a food deficit, account for over 99% of the world's production.¹ Most of the banana fruit produced in India, China and Indonesia is the sweet, eating variety 'Cavendish', while those produced in low-income countries are high-starch plantain varieties that are used primarily for cooking.² Australia's production in 2020–1 was just under 362 000 t, mainly of the Cavendish variety (97%), with Queensland producing 94% of the fruit. The Australian banana industry, with an annual farmgate value of approximately \$AUD 597 million, is one of the largest horticultural industries in the nation.³

There are three endemic *Musa* species in Australia, but they are not commercially cultivated as the fruit contains hard seeds and little pulp. Planting materials of edible banana varieties were transported on the First Fleet (1788), and although plants were grown around Sydney in the first few decades of colonisation, it was not until the Moreton Bay colony (later Brisbane, in sub-tropical southern Queensland) was established in 1825 that bananas were grown on a semi-commercial scale. The industry thrived for almost five decades until a disease began to appear in some of the plantations around Brisbane. In 1876, the physician and naturalist Joseph Bancroft was the first person to describe the symptoms of the disease, which he believed were caused by a

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¹Anonymous (2023a)

²Heslop-Harrison and Schwarzacher (2007) p. 1074. Mostert and others (2017).

³Anonymous (2023b).

fungus after he observed fungal threads (hyphae) in the vascular tissue of the pseudostems of affected plants.

Subsequently, outbreaks of a similar disease decimated banana plantations in central America in the early 1890s and was named Panama Disease by the scientific community, despite its discovery having been made in Australia a decade and a half earlier. In this paper we outline the early development of the banana industry in Australia, discuss the findings of Bancroft and the Queensland plant pathologist Henry Tryon and review the work of the American scientists Erwin Frink Smith and Elmer Brandes.⁴

Early history of the banana as a commercial crop

The history of the development of the edible banana industry has been written by many authors,⁵ so only a summary will be presented here, focusing on the Australian industry. De Langhe and others have written that the domestication of banana was complex and occurred in ‘several stages, often separated by time and place’.⁶

Edible bananas are either diploid or triploid genomes of *Musa acuminata* (A genome) or hybrids of this species and *Musa balbisiana* (B genome). Natural hybridisation led to the evolution of parthenogenesis (development from an embryo that has not been fertilised) in both sweet banana and plantain types, while humans selected plants whose fruit had a high pulp content.⁷ The taxonomy of *Musa* is complex, with varieties/types being grouped according to the relative proportions of the A and B genomes that they contain; for example, both the Gros Michel and Cavendish varieties have a triploid AAA genome and are classified in the Cavendish subgroup, whereas Lady Finger has a triploid AAB genome and is classified in the Pome subgroup.⁸

The variety that ultimately became known as Gros Michel was the first widely grown, commercial banana variety. The available evidence suggests that the French explorer Nicholas Baudin collected planting material of this variety in southern China in the late 1780s while on a covert trade and collecting mission.⁹ On his trip back to Europe a few

years later, he stopped at Trinidad, where he left his natural history collection, before proceeding to Martinique. Planting material ultimately made its way to Martinique where the local growers were impressed, naming it Figue Boudin (Baudin’s fig).¹⁰ In 1835 the French botanist Francois Puyat transported planting material from there to Jamaica where it became known as Boyo’s banana.¹¹ The variety dominated commercial production in central American and Caribbean countries until the mid-1950s when fusarium wilt decimated its production.¹²

The variety Gros Michel was replaced by the shorter Cavendish variety, which was resistant to the strain (race 1) of the Fusarium wilt pathogen. ‘Cavendish’ is considered as being a native of China, from where the Irish naturalist Charles Telfair (1788–1833) collected specimens in the mid-1820s and took them to Mauritius to grow alongside other *Musa* species in his garden. From there, two plants were sent to Burryhill (England) in 1829 by Telfair, where they were purchased by Messrs Young of Epsom.¹³ One of the plants was then sold to William Cavendish (1790–1858), the sixth Duke of Devonshire, where it was raised and multiplied in a glasshouse at the Chatsworth House estate, Derbyshire, by (Sir) Joseph Paxton (1803–65), who was the duke’s head gardener at the time. The Cavendish banana was first described in 1837 as *Musa cavendishii* (the Cavendish plantain) by Paxton in honour of his employer.¹⁴

Musa in Australia

The first British record of *Musa* in Australia was on Captain James Cook’s (1728–79) first voyage of exploration to New Holland (1768–71). After his ship *HM Endeavour* was wrecked on the Great Barrier Reef in June 1770, it was beached for repairs in the Endeavour River near the present day town of Cooktown.¹⁵ Cook wrote in his journal that a small food-gathering party led by Mr Gore brought back two bunches of ‘wild plantain’ (fruit), the smallest that he had ever seen, and the pulp, though it tasted well, was full of small seed.¹⁶ The botanist (Sir) Joseph Banks (1743–1820)

⁴We have used newspaper articles (<https://trove.nla.gov.au/newspaper/>), books written by First Fleeters and others, publications in scientific journals, internet sites and other sources to gather information for this paper. Many of these sources were accessed through interrogations of e-libraries, particularly the Biodiversity Heritage Library (<https://www.biodiversitylibrary.org/>), HathiTrust Digital Library (<https://www.hathitrust.org/>) and Internet Archive (<https://archive.org/>).

⁵Such as Heslop-Harrison and Schwarzscher (2007). Koeppel (2008). De Langhe and others (2009).

⁶De Langhe and others (2009) p. 165.

⁷Perrier and others (2011).

⁸Pegg and others (2019). Viljoen and others (2020) p. 161.

⁹West-Sooby and others (2015).

¹⁰Koeppel (2008) p. 33.

¹¹Koeppel (2008) p. 33.

¹²Viljoen and others (2020) p. 159.

¹³Paxton (1837) p. 51.

¹⁴Paxton (1837) pp. 51, 52.

¹⁵Parkin (1997) pp. 299–323, 329–331. Cook (1821) pp. 128, 139.

¹⁶Cook (1821) p. 143.

also found the plantain (*Musa* sp.) growing wild, noting that its fruit was ‘so full of hard, round, black seeds that it was scarce edible’.¹⁷

Three species of *Musa* are endemic to Australia, *M. jackeyi* (synonym *M. hillii*) (Johnson River banana), *M. acuminata* subsp. *banksii* (native banana) and the now extinct *M. fitzalanii* (Daintree River banana).¹⁸ *Musa jackeyi* has a relatively small geographic distribution south of Cooktown; *M. fitzalanii* was only ever known from a single plant, the type specimen, from the Daintree River area; and the natural range of *M. acuminata* subsp. *banksii* is New Guinea and the east coast of Australia from Cape York to Paluma, with two records from near Cooktown.¹⁹ Therefore, it is most likely that the *Endeavour*’s crew tasted the fruit of *M. acuminata* subsp. *banksii*. In the second half of the nineteenth century, the Queensland Government Botanist, Frederick Manson Bailey (1827–1915), wrote that the Indigenous name for *M. acuminata* subsp. *banksii* was ‘chatum’ and the author H. Dick that the Aborigines south of Cairns ate the fruit, and those north of Mossman ate starch extracted from the inside of the pseudostem.²⁰

The establishment of a banana industry in Australia

Banana plants collected at Rio de Janeiro were brought to New South Wales on the ships of the First Fleet transporting British convicts, soldiers and the colony’s authorities in 1788.²¹ It is not known if the plants survived the voyage or were planted at Sydney Cove. The first mention of banana in the new colony is in August 1790, when an officer wrote to Joseph Banks that there was ‘spontaneous’ production of banana plants on Norfolk Island,²² approximately 1000 km east of the Australian coast, which was used as a penal colony for the worst convicts on the mainland. Judge Advocate David Collins (1756–1810) considered that the discovery of regular rows of banana plants as well as stone chisels and adzes as evidence that Norfolk Island had been

inhabited by others at some time in the past.²³ Archaeological evidence suggests that east Polynesian seafarers colonised the island in the fourteenth or fifteenth century, but only for a few generations, as when Cook landed in 1774, the island was uninhabited.²⁴ On the island, these plants, and those generated from planting material sourced from Brazil, ultimately produced hands (a bunch of five or so bananas) of 40–80 lb (18–36 kg) each.²⁵

In 1793, Captain Watkin Tench (1758–1833) wrote that the banana was introduced into the New South Wales colony from Norfolk Island.²⁶ However, in his list of non-indigenous plants for 1803, Governor Phillip Gidley King (1758–1808) noted that the banana was scarce and did not succeed in ‘this part of the colony’ (around Sydney).²⁷ Some settlers apparently had some success, because a few years later it was announced that two banana trees growing in a gentleman’s garden a few miles from Sydney had produced two–three dozen hands.²⁸ Decades later, bananas were still being grown around Sydney in sheltered private gardens.²⁹ Despite the difficulty in growing them, there must have been enough bananas cultivated for some people to attempt to make a profit from their sale. The first record of banana fruit offered for sale in Sydney was in the *Sydney Herald* of 12 November 1838; they cost sixpence each.³⁰

The Quaker missionary James Backhouse (1794–1869) saw banana plants growing at the town of Brisbane on a visit in 1836 just twelve years after its establishment.³¹ It is not known who brought the first banana planting material into the Brisbane region and where that material was sourced from, but it is possible that it had been brought to the colony from Sydney. The soil and subtropical climate of Brisbane was considered to be ideal for growing bananas, and the free colonists were encouraged to grow bananas and export them to Sydney.³²

The identities of the varieties that were first grown in Australia are unknown, but as early as 1847 the nurseryman George Anstey was offering plants of ‘disease-free’ Cavendish for sale in South Australia.³³ Eleven years later there was a classified advertisement in the *Moreton Bay*

¹⁷Parkin (1997) p. 337.

¹⁸Bailey (1902) p. 1598. Anonymous (2022a, 2022b, 2022c, 2022d).

¹⁹Anonymous (2022b, 2022c). Bailey (1902) p. 1599.

²⁰Bailey (1889) p. 62. Dick (1994).

²¹Collins (1798) section 2, paragraph 67.

²²Anonymous (1892).

²³Collins (1798) chapter 14, paragraph 30.

²⁴Sampson (2005).

²⁵King (1896) p. 150.

²⁶Tench (1793) chapter 17, paragraph 16.

²⁷King (1803).

²⁸Anonymous (1809).

²⁹Anonymous (1837).

³⁰Anonymous (1838).

³¹Backhouse (1843) p. 358.

³²Anonymous (1848).

³³Anonymous (1847).

Courier of 23 October 1858 offering plants of ‘true Cavendish’.³⁴ In 1865, Captain Wickham was growing plants of Cavendish (*M. cavendishii*; as written) and ‘Sugar’ banana (*M. sapientum*; as written) at Newstead, a now inner suburb of Brisbane. Although the Cavendish was the best for quality and quantity it suffered from frost damage, unlike the ‘common banana’.³⁵

By 1875, there were at least six banana varieties or types being grown in southern Queensland. An article in the *Queenslander* of January 1875, listed the following and their attributes—(i) Cavendish, with large bunches of sweet, highly-flavoured fruit, (ii) Lady’s Finger, probably from Tahiti, and the best banana, (iii) Sugar Banana, well known but not good for eating until thoroughly ripe, (iv) Common Banana such as the Charlotte, hardy and prolific, (v) Dacca (Pear Banana), a very superior kind, and (vi) Green Dacca, a culinary (cooking banana).³⁶ The Gros Michel variety was not mentioned.

Over time it became apparent that the tropical and frost-free sub-tropical districts of Australia were the best places to grow banana on a plantation scale. An article in the *Telegraph* of 11 June 1889, reported that 8000 dozen hands of banana fruit had arrived in Brisbane in *Tahshaw* from Maroochie (Maroochydhore) in southern Queensland.³⁷ The interstate export of banana fruit from Queensland to the southern Australian states continued in earnest, because a newspaper article reported that in 1895, 307 746 bushels (1 bushel = 100 bananas) of fruit had been landed from Queensland, while only 4704 bushels were imported from New South Wales and 5532 bushels from Fiji.³⁸

Chinese introduction of banana into north Queensland

Many websites (such as, www.abgc.org.au/our-industry/history-of-bananas) state that the Chinese (and perhaps canecutters from Fiji) introduced the banana into north Queensland in the 1870s, but there is no reliable published information to confirm or reject this statement. However, it is accepted that the Chinese, particularly after the Palmer River gold rush had ended in the early 1880s, began to cultivate the banana along the tropical north coast of

Queensland. On one plantation and probably many more, the bananas were grown initially to feed ‘Kanakas’ (cane-cutters from the Pacific Islands) who were working on the nearby sugar plantations, but an excess of production allowed the owners to export banana bunches to southern states.³⁹ In this article it is also stated that the Cavendish was the only variety grown in the tropics. As the banana industry expanded in north Queensland, the economics of growing bananas in sub-tropical southern Queensland became less attractive to the old ‘hands’ who sold their land around Brisbane for the building of houses.⁴⁰

Warwick Frost wrote that Queensland Royal Commissions in 1889 and 1897 found that the Chinese leased lots of land of about twenty acres (approximately 8.1 ha) from European landowners that they cleared of trees and grew a variety of crops including vegetables, rice, bananas and other fruit.⁴¹ The Chinese farmers cleared trees on new ground, turned over the soil with hoes, grew bananas for five or six years (when the plants needed to be replaced), then moved onto new ground and repeated the cycle.⁴² This practice led to accusations that after the Chinese farmers had depleted the soil of nutrients, they simply moved on rather than practice sustainable agriculture.⁴³ In 1897, it was established that in the Cairns district the Chinese dominated the banana industry while Europeans were dominant in the sugar industry. Chinese merchants were also very active in the banana trade in Sydney and Melbourne during this time and brought prosperity not only to their families but also the Chinese communities in those cities.⁴⁴

After the turn of the twentieth century, Chinese-run agricultural production in northern Queensland declined due mainly to prejudice, the impact of *The Restriction of Chinese Immigration Act* of 1888, the desire of Europeans to dominate agriculture and the death of the older Chinese agriculturalists.⁴⁵ These factors, combined with the impacts of tropical cyclones in 1906 and 1911, interstate restrictions on banana imports due to infestations of the Queensland fruit fly (*Bactrocera tryoni*) and the lack of action on the part of Chinese growers to ensure that consignments were free from fruit fly contributed to a rapid decline in the banana industry and a mass exodus to China or to the Atherton Tableland where many Chinese grew maize.⁴⁶ The impact of these influences is reflected in the annual production of

³⁴Anonymous (1858).

³⁵Anonymous (1865).

³⁶Anonymous (1875a).

³⁷Anonymous (1889).

³⁸Anonymous (1896).

³⁹Anonymous (1887).

⁴⁰Cooksley (1901) p. 148.

⁴¹Frost (2002) in 2000 working paper, pp. 5–6.

⁴²May (1984) p. 18.

⁴³May (1984) p. 17.

⁴⁴Yong (1964). p. 28

⁴⁵Frost (2002) in 2000 working paper, pp. 6–7.

⁴⁶May (1984) pp. 27–29.

bananas in tropical Queensland. In 1899 over 3.6 million bunches (432 million bananas) were grown in the tropics, just a year later approximately 2.3 million bunches were grown, but in 1911 only 747 000 bunches were produced.⁴⁷

The failed Gros Michel variety in Australia

It seems that the Gros Michel variety was never grown in Australia to any extent. Bananas imported from Fiji provided significant competition to Australian-grown bananas in the latter part of the 1800s and it has been stated that the Fijian bananas were of the Gros Michel variety.⁴⁸ Apparently, consumers in the southern states of Australia preferred the Fijian Gros Michel bananas to the Australian Cavendish bananas, mainly because of their shape and larger size.⁴⁹ In addition, the twelve-day sea journey from Cairns to Melbourne meant that Cavendish bananas had to be harvested when green and unripe, and this combined with rough handling by wharf workers resulted in fruit were often of poor quality when they arrived in Melbourne.⁵⁰

In response to the southern demand, the Mourilyan Syndicate Ltd in North Queensland ordered hundreds of young plants of Gros Michel that were to be planted along the tropical coast.⁵¹ However, within a few years it was evident that the new variety had several deficiencies that made the variety unpopular with commercial growers. Its height made it susceptible to destruction by high winds and cyclones; it was a 'shy bearer' because it needed very heavy rain to fruit, which made it unsuitable from growth in the subtropics; and the fruit ripened very quickly.⁵² Giving evidence at an Interstate Commission, Mr P. Outridge was more forthright when he stated that the Gros Michel was 'an absolute failure'.⁵³

By the end of the 1920s, the variety had 'practically gone out of cultivation in Fiji', had been superseded by Dwarf Cavendish and was not being grown 'to any extent in Australia'.⁵⁴ The writer 'Cudgerie' apparently had had enough of the Gros Michel when, referring to advice about the difficulties of transporting the soft-skinned Cavendish relative to the hard-skinned Gros Michel, he wrote that: 'one of the greatest handicaps that the banana grower suffers is the expert, but absolutely impracticable bunk that he gets,

instead of a properly digested essence drawn from local experience'.⁵⁵

The outbreak of the banana disease in Australia

One of the first records of a new banana disease in Australia was in an article, 'The Farm and Garden Memoranda for October' in *The Queenslander* of 30 September 1871.⁵⁶ It reported that the 'stems' (botanically pseudostems) of banana plants in plantations around Brisbane began to rot into a soft, wet mass from the tops, the roots became rotten and the 'hearts' of the pseudostems near the base ultimately turned black (Figs 1, 2). The disease had been blamed by various people on poor drainage, worn out plants, exhaustion of the soil (from monoculture of the banana) and in a premonition of the future, climate change. However, the writer noted that the disease also occurred on plants grown in fresh soil. They recommended replacing the old plants with new ones, and the importation of new varieties from overseas locations such as Java.

The Moreton Farmer's Association was so concerned that in late 1873 they formed a sub-committee to get to the cause of 'the canker', a name which had been given previously to the disease by some growers.⁵⁷ The sub-committee produced a circular for growers to answer a series of questions and provide comments so they could determine the cause of the problem. Apparently, little was achieved because in mid-1875 a Sydney paper cynically reported that although the 'committee of wise men ... met, and met, and met again', 'the cause baffled them'.⁵⁸

There was anecdotal evidence at the time that some varieties were more susceptible than others. At a meeting of the East Moreton Farmer's Association (EMFA) in February 1874, attendees were told that the most susceptible variety was the common banana, followed by the Sugar banana (AAB, Silk subgroup) and the Cavendish.⁵⁹ It was also stated that rich manuring and 'high cultivation' increased the disease. On the contrary, Mr John McDonald, superintendent of the prison on St Helena Island near Brisbane, recommended that banana plants should be routinely removed after four or five years and new plantlets

⁴⁷Yong (1964) appendix 1, p. 33.

⁴⁸Anonymous (1930).

⁴⁹Scriven (1914).

⁵⁰May (1984) p. 23.

⁵¹Anonymous (1912).

⁵²'Banana Planter' (1915).

⁵³Outridge (1914).

⁵⁴Greer (1929).

⁵⁵'Cudgerie' (1928).

⁵⁶Anonymous (1871).

⁵⁷Anonymous (1873).

⁵⁸Anonymous (1875b).

⁵⁹Anonymous (1874).



Fig. 1. Banana plants variety Ducasse affected by Fusarium Wilt caused by *Fusarium oxysporum* f.sp. *cubense* Race 1, Duranbah Qld, 15 December 2015, photo by Andre Drenth.



Fig. 2. Internal symptoms in pseudostem of banana variety Ducasse affected by Fusarium Wilt caused by *Fusarium oxysporum* f.sp. *cubense* Race 1, Duranbah Qld, 15 December 2015, photo by Andre Drenth.

from healthy plants be grown in well manured and cultivated soil.⁶⁰ No wonder the growers were confused.

Early in the investigation, the EMFA invited the medical doctor and naturalist Dr Joseph Bancroft (1836–94) (Fig. 3) to visit Mr. Fleming's affected banana plantation at Eagle Farm in February 1874 to investigate the new banana disease. There, plants of Lady Finger (*Musa acuminata* Colla × *M. balbisiana* Colla) were affected by the disease but plants of Cavendish were not. The EMFA would have chosen Bancroft because he was one of the few university-educated individuals (Manchester Royal School of Medicine and Surgery in England and the University of St Andrews in Scotland) in the district with a scientific interest in

agriculture. After arriving in Queensland, he established experimental gardens at his properties in Brisbane, and collaborated with Australia's first wheat breeder, William Farrer.⁶¹ At various times Bancroft was president of the Philosophical Society of Queensland, the Royal Society of Queensland, and the Medical Board of Queensland.⁶²

In 1876, Bancroft wrote a short report (published in 1877) of just over 400 words on the disease, that was presented to the Queensland Legislative Assembly as part of the *Report of the Board Appointed to Enquire into the Causes of Disease Affecting Livestock and Plants, Queensland*.⁶³ He believed the disease to be of fungoid origin because he found mycelium (fungal threads) in the 'spiral threads ... of the air vessels' (elements of the vascular bundles) and opaque and ovoid 'scleroids' in the 'air cells' (probably parenchyma cells) of the lower parts of discoloured

⁶⁰McDonald (1875).

⁶¹Bancroft (1885), p. 176. Anonymous (2018). Mackerras (2021).

⁶²Anonymous (2012).

⁶³Bancroft (1877) p. 1032.



Fig. 3. Joseph Bancroft, 'eminent medical scientist, first in the world to discover the adult filarial worm in 1876', State Library of Queensland, Accession number: D1-12-89, <https://hdl.handle.net/10462/deriv/71103>.

leaf sheaths. Internally in diseased stools, the 'spiral threads' were bright orange to mahogany, and the discoloration extended into the new buds which, if planted, would carry the disease. Small dark spots developed in the leaves (blades), ruby red spots and streaks were seen on the inside surface of the leaf sheaths and a purple discolouration was found in the cells of the lower parts of the sheaths. He also noted that many of the new varieties were affected by the disease but only the common banana died before fruiting.⁶⁴

The results of the survey of banana growers were presented in the report and revealed that banana production in the Moreton region of southern Queensland had deteriorated over the past twenty five years probably due to the new disease, while plantations in the Maryborough, Rockhampton and Townsville regions where banana had been grown for up to twenty years were not affected. For growers in the Moreton region, Bancroft recommended that planting material be sourced only from healthy plants.⁶⁵

The identification of the causal agent of Fusarium Wilt

In 1904, American B. McKenney wrote that a serious disease that was devastating banana plantations in Costa Rica, Panama, Nicaragua, Honduras, and Guatemala had been first noticed in a few isolated locations in Panama in 1890.⁶⁶ The description of its symptoms was identical to that of Bancroft's, fourteen years earlier. It is widely accepted that the rapid spread of the disease, particularly in the Caribbean and central American countries was most likely to have occurred by the trade of infected planting material between countries.⁶⁷

In 1910, the American bacteriologist Erwin Frink Smith (1854–1927) (Fig. 4) reported the findings of his investigations of a banana disease in Cuba,⁶⁸ which had the same symptoms as the Australian one. Interestingly, there is no evidence that Smith ever saw field-grown banana plants affected by the disease, relying instead on the descriptions made by Cuban growers and on specimens sent to him. In these diseased samples, Smith found a small amount of mycelium and a few microconidia (spores) in the vessels of vascular bundles in the pseudostems of diseased plants and consistently isolated a species of *Fusarium* from the infected tissue. Smith and his co-workers inoculated the midribs of leaf blades, leaf sheaths and pseudostems of several large (20 ft high and 1 ft in diameter (6.1 and 0.3 m respectively) banana plants with mycelium from cultures of the *Fusarium* sp. After an unspecified period, he noted that the vascular bundles of the petioles up to 8 ft (2.4 m) from the site of inoculation were brown to purple. His team then successfully re-isolated the fungus from those tissues. Smith stated that the experiment was not continued because the glasshouses in which the plants were being grown were demolished. He did not describe the diagnostic symptoms of the new banana disease on inoculated plants, namely wilting and death of the plants, internal discoloration of the pseudostems and rotting of the roots.

Smith provided a brief description of the fungus that he had found, noting that it formed microconidia and macroconidia in artificial culture and produced red and purple pigments in the culture media. However, he did not provide any information on the morphology of the two types of conidia, more specifically their shape, dimensions and septation. He named the fungus *Fusarium cubense*, which differed from other species of *Fusarium* sometimes found in banana plants in its 'location in diseased banana plants' and the discoloration of the vascular bundles.⁶⁹

⁶⁴Bancroft (1877) p. 1032.

⁶⁵Bancroft (1877) p. 1032.

⁶⁶McKenney (1910) pp. 750–751.

⁶⁷Mostert and others (2017). Pegg and others (2019).

⁶⁸Smith (1910) p. 775.

⁶⁹Smith (1910) p. 775.

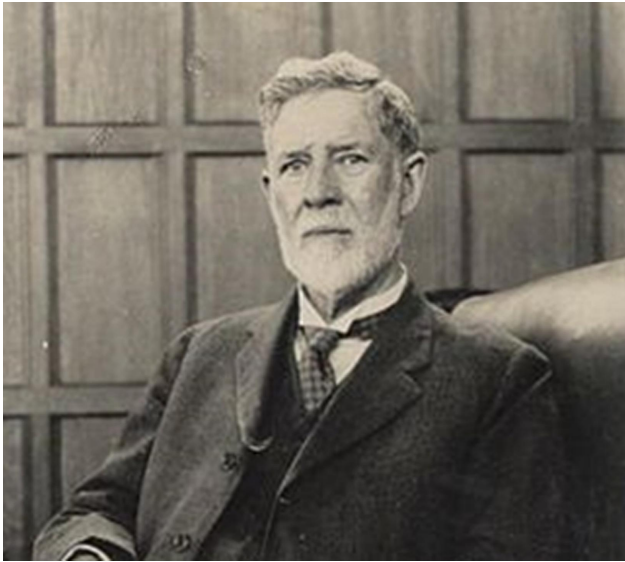


Fig. 4. Erwin F. Smith (1854–1927), 1926, photographer unknown, Embryo Project Encyclopedia, <http://embryo.asu.edu/handle/10776/2872>.

Neither McKenney nor Smith used the name 'Panama Disease' for the banana disease found in central America or the Caribbean, nor did they acknowledge Bancroft's discovery of the disease in Australia.

The re-appearance of the disease in Australia

In response to numerous enquiries made by banana growers to the Queensland Department of Agriculture and Stock, a short paper on the 'Natural enemies of the banana occurring in Queensland', written by the Queensland entomologist and vegetable pathologist Henry Tryon (1856–1943), was published in the February 1912 edition of the *Queensland Agricultural Journal*. Tryon wrote that the disease had long been present in southern Queensland and had been studied by Bancroft in the mid-1870s.⁷⁰ He described its symptoms as the leaves becoming chlorotic and ultimately dying, stunted plants, dark red-purple or red spots on the roots near the corms and brown patches inside the roots. The disease usually became evident during flowering time (January–February), with the 'Sugar' banana and plantain bananas being highly susceptible. Suckers from infected plants inevitably grew into diseased plants. There is no evidence that Tryon undertook any scientific investigations on the disease.

⁷⁰Tryon (1912) p. 116.

⁷¹Tryon (1912) pp. 116–118.

⁷²Pegg and others (2019).

⁷³Brandes (1919) p. 339.

⁷⁴Brandes (1919) p. 344.

⁷⁵Brandes (1919) p. 344.

Tryon also reported that Bancroft had found fungal mycelium in the vascular tissue and that the disease was possibly caused by a species of *Fusarium*. He believed that it was identical or closely related to a malady (Panama Disease) of banana that was devastating plantations in Central America and some islands in the West Indies at the time.⁷¹ For some reason, Tryon did not discuss Erwin Smith's findings despite that fact that Smith had published that work two years before Tryon's publication. Perhaps Tryon was unsure that the disease in Australia was the same as the South American one and/or not convinced that Smith had proved beyond doubt that *Fusarium cubense* was the causal agent.

Neither Bancroft nor Tryon speculated on the initial mode of introduction of the pathogen into Australia, but it was most likely by the movement of asymptomatic planting material, or perhaps on soil adhering to such material. The fungus that Smith named *Fusarium cubense* produces asexual, thick-walled chlamydospores in infected banana tissue, which are released into the soil when the infected host tissue breaks down.⁷² In fact, there is no scientific evidence about when the pathogen arrived in Australia or the source of the infected material. It is possible that *F. cubense* had been in Australia for many years, at a very low incidence before it was discovered by Bancroft. Undoubtedly, the practice of growing bananas in monoculture plantations where disease levels would have increased gradually over time contributed to the apparent 'sudden' appearance of the disease in Australia.

Elmer Walker Brandes

Another American scientist, Elmer Walker Brandes (1891–1964), who was the sugarcane specialist at the United States Department of Agriculture (USDA) and later the pathologist-in-charge of several divisions in that organisation, was a well-known and respected scientist who worked on the botany, agronomy, entomology and pathology (mostly viruses) of sugarcane. Prior to his appointment in the USDA, he undertook a doctoral study on banana wilt initially in Puerto Rico and later at several universities in the USA.⁷³

In 1919, he published a paper of almost fifty pages that detailed his studies on the disease that he preferred to call 'Banana Wilt' rather than some of its other names, including Panama Disease, 'banana droop', and 'tired bananas'.⁷⁴ He doubted that the name Panama Disease was first used in the Panama because 'it would not there be particularly descriptive', rather it was probably first used in Surinam (now known as Suriname, Central America), where a disease identical to that in Panama was first observed in 1906.⁷⁵

In a section on the ‘History and previous literature’ (of the disease), he wrote that Tryon’s account of the disease in Australia in 1912 was incomplete, so he was uncertain if it was the same disease as his ‘Banana Wilt’.⁷⁶ Also, Brandes wrote that Erwin Frink Smith had neither described the symptoms of the disease in detail nor provided an adequate description of the fungus.⁷⁷ In his paper there is no mention of Bancroft’s report which predates those of all other researchers.

Brandes described the symptoms and signs of the disease in detail, which are summarised as yellowing and wilting of lower leaves and petioles, wilting of leaves, stunting of plants, longitudinal splitting of the outer leaf bases, and small bunches of bananas. He noted that white sporodochia (sporing bodies) of the *Fusarium* developed on the leaf blades, petioles and bases. Internally, the vascular bundles in the pseudostems turned yellow or light brown and those in the rhizomes became red to reddish brown and later purple or black. The roots rotted and decayed.⁷⁸ He also provided detailed descriptions of the morphology, growth, and physiology of the fungus, which he had also isolated from soil adjacent to infected plants.⁷⁹ His description of the symptoms agree in most respects with those provided by Bancroft in 1876 and Tryon in 1912.

To prove conclusively that Smith’s *Fusarium cubense* caused symptoms of Banana Wilt, he planted healthy banana ‘bulbs’ into steam-sterilised soil in large cement cylinders. The contents of *Fusarium* cultures growing on cornmeal agar in one litre glass flasks were added and mixed through the soil in each of ten cylinders. Eight months later, every inoculated plant had the symptoms of wilt, while the ten control plants were still healthy. Brandes and his team re-isolated the fungus, which had the same cultural characteristics of the original isolate, from the inoculated plants,⁸⁰ thereby satisfying Koch’s Postulates. In his taxonomic description of the fungus, Brandes noted that most isolates produced a strong odour when grown on steamed rice agar; these he named *Fusarium cubense*. However, there were some isolates that did not have an odour—these he named *Fusarium cubense* var. *inodorum*.⁸¹

The disease in the modern world

In 1940, *F. cubense* was renamed *Fusarium oxysporum* f.sp. *cubense*.⁸² There are currently four recognised races (strains) of *F. oxysporum* f.sp. *cubense*, three of which are present in Queensland. Race 1 attacks the varieties Lady Finger, Sugar and Ducasse only in eastern Australia, race 2 attacks the varieties Buggoe and Blue Java (cooking bananas) in northern New South Wales, while subtropical race 4 attacks all varieties including the main variety Cavendish in southern Queensland and northern New South Wales.⁸³

Tropical race 4 of *F. oxysporum* f.sp. *cubense*, often called *F. oxysporum* f.sp. *cubense* TR4, is one of the most serious threats to banana production worldwide, including countries in Asia, the Middle East, as well as in India, Pakistan and Mozambique.⁸⁴ In 2019, the fungus was renamed *Fusarium odoratissimum* based molecular and morphological studies, and the production of a strong, stale odour when grown in glassware.⁸⁵ However, two years later Torres Bedoya and others cast doubt on the validity of the new name when they ‘discovered that the data do not robustly support the proposals’, specifically ‘several apparent discrepancies and errors in the published (molecular) phylogenies’.⁸⁶

The world’s most popular eating variety, Cavendish, is susceptible to TR4.⁸⁷ Tropical race 4 was first detected in Australia near Darwin, Northern Territory in 1997, and has been found on eight properties near Tully in northern Queensland since 2015.⁸⁸ The pathogen may have entered Australia on infected planting material or in soil on vehicles, but how and when that occurred has not been established. It is a Category 1 restricted matter under the Biosecurity Act 2014, with surveillance, identification and eradication being managed in the Biosecurity Queensland’s Panama TR4 Program.⁸⁹

Management of the disease today is through the use of clean planting material from disease-free sites or tissue culture, avoidance of fields with a previous history of the disease and those with poorly drained soils, and quarantine measures to avoid movement of infested soil and planting material. Detection of TR4 on a property results in strict, monitored, quarantine measures.⁹⁰ The rapid and accurate identification of races of the fungus is critical and is

⁷⁶Brandes (1919), p. 346.

⁷⁷Brandes (1919) p. 346.

⁷⁸Brandes (1919) pp. 353–356.

⁷⁹Brandes (1919) pp. 350–359.

⁸⁰Brandes (1919) pp. 367–373.

⁸¹Brandes (1919) p. 374.

⁸²Snyder and Hansen (1940) pp. 64–67.

⁸³Grice and others (2009).

⁸⁴Maryani and others (2019) p. 155.

⁸⁵Maryani and others (2019) pp. 159–160.

⁸⁶Torres Bedoya and others (2021).

⁸⁷Anonymous (2022e).

⁸⁸Anonymous (2022f, 2023c).

⁸⁹Anonymous (2022e).

⁹⁰Anonymous (2022f).

undertaken using molecular techniques and Vegetative Compatibility Group (VCG) studies.⁹¹

Conclusion

Was Bancroft, who wrote the first description of the symptoms and signs of the disease, given due recognition as the discoverer of Fusarium Wilt of banana by the first professional plant pathologists who worked on the disease? Our answer is 'NO'. Smith dismissed Bancroft's findings (as reported by Tryon), while Brandes wrote that Henry Tryon's description was not detailed enough to be certain that he was referring to Fusarium Wilt.⁹² The highly respected Queensland plant pathologists, John Howard (Jack) Simmonds (1901–92) and Kenneth (Ken) Pegg and others are in no doubt about the priority of Bancroft's discovery.⁹³

Brandes also claimed that the first published record of the disease was in Honolulu in 1904 by the USDA horticulturalist James Edgar Higgins (1873–1938), and although he called it a 'meagre account', Brandes concluded that Higgins had probably described Fusarium Wilt.⁹⁴ Higgin's account of the disease stated 'It affects the central growing part of the banana plant and is first observable by the darkened color of the young leaves before they open. The decay finally results in the death of the plant though suckers continue to grow.'

Higgins had sent specimens to the USDA vegetable pathologist and physiologist (not named, but Erwin Frink Smith was the chief of Plant Pathology between 1889 and 1927) in Washington who replied that the disease was caused by 'a Fusarium (which) is present in a state of most luxurious growth'.⁹⁵ The description of the symptoms given by Higgins was far less informative than those provided by both Bancroft and Tryon.

Careful analysis of Bancroft's and Tryon's descriptions of the symptoms of the disease leave no doubt that they were writing about Fusarium Wilt. It can be stated with certainty that Bancroft's investigations of Fusarium Wilt were the first of that nature in Australia, decades before the first Government 'Vegetable pathologists', Daniel McAlpine (Victoria), Nathan Cobb (New South Wales) and Henry Tryon (Queensland) began their scientific investigations. This little-known agricultural scientist deserves our recognition.

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⁹¹Mostert and others (2017). Pegg and others (2019).

⁹²Smith (1910). Brandes (1919) p. 346.

⁹³Simmonds (1986) p. 2. Pegg and others (2019).

⁹⁴Brandes (1919) p. 345.

⁹⁵Higgins (1904) p. 31.

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