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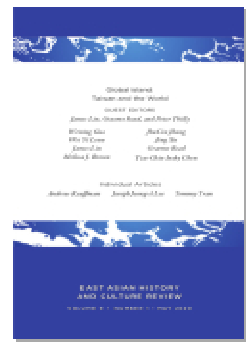

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# Horai Rice in the Making of Japanese Colonial Taiwan

WEI YI LEOW

*National University of Singapore*

**ABSTRACT**

In 1912, Eikichi Iso arrived to serve as a plant breeder in the Japanese colony of Taiwan. Iso and his researchers developed crossbred Horai rice that produced the round grains desired by Japanese consumers. This article explains how Horai rice made Taiwan into an economically viable possession of the Japanese Empire. Iso matched the terrain and conditions of Taiwan to the regions of the Japanese home islands closest in character, and the varieties from each region were selected for experimentation at field stations located in the matching Taiwanese region. The experiments yielded new varieties of rice that fostered trade relations between Taiwan and the home islands. This change brought about higher incomes but also increased costs for the farmers. The addition of a new cash crop unsettled Japanese attempts to manage the sugar industry, instigating greater state intervention in rice markets, even as war demand meant that Taiwanese rice became indispensable. The success of Horai gave Taiwan an identity as a rice colony, which its leaders sought to leverage as expertise to colonize newly conquered Hainan. The movement of people, ideas, and the genetic materials of rice plants created a "Japanized" Taiwan that in turn expanded beyond the shores of the island colony.

KEYWORDS: Taiwan, Japanese Empire, history of agriculture, history of science, rice, Horai, genetics

> The average yield of rice given for Taiwan is 13 *koku* per hectare. . . . At the time of annexation the average yield was only 6 *koku* per hectare. (Mendiola 1949, 69)

Nemesio B. Mendiola, a plant breeder with the Department of Agriculture of the Philippines, visited Taiwan in 1944 to observe the noteworthy accomplishments in rice cultivation science and technology on Japan's island colony. This article presents the way colonial ideology in Taiwan was shaped by the perceived power of scientific research witnessed by Mendiola and other observers from further afield. The focus of this article is the work of Eikichi Iso, a Japanese plant breeder active in Taiwan from 1912 until the 1950s, after the Republic of China took control of Taiwan. He succeeded in crossbreeding Japanese varieties with others to produce new types that could be grown on Taiwanese soil to produce rice grains preferred by Japanese consumers. These varieties, known collectively as Horai, transformed both the internal economy and external trade of Taiwan. The success of Horai as a cash crop interfered with the policies laid out by the Government-General of Taiwan to protect Japanese sugar interests. Yet, as Horai rice became an integral part of the fabric of the Taiwanese political economy, Taiwan's Japanese rulers progressively adopted it as a key factor in their decision making and their vision for the future of the colony.

Taiwan was a place remade by colonialism long before its annexation by Japan in 1895 and the subsequent Japanese rule. In the mid-seventeenth century, Dutch colonists brought sugar as a crop along with Chinese farmers for their skills and numbers, and exported rice to faraway Persia and the Netherlands (Koo 2015). After the Qing Empire took Taiwan in the 1680s, output growth was achieved not through the application of new technology but with the opening of new land for agriculture and the addition of labor inputs (Isett 1995). As a result, Taiwan experienced close to zero per-capita growth at 0.3 percent annually in the late Qing period (1880s–1890s), but this rate increased to more than 2 percent under Japanese rule (Wu 2001, 3). Taiwan came to be "islanded"—a concept proposed by historian Sujit Sivasundaram (2013)—via the action of successive colonizing powers, as new links were forged while old relations were disconnected. Such was the palimpsest of plants, people, and technologies fused by various forms of alien governance that provided the base for Japanese-ruled Taiwan and its agriculture.

## IMPERATIVES FOR THE DEVELOPMENT OF COLONIAL SCIENCE

Europeans' journeys of exploration and conquest to Africa and Asia beginning in the late 1400s brought them into contact with unfamiliar flora and fauna. Their exploitative mode of production frequently led to despoliation of the environment. Measures to curb the early reckless deforestation engendered by negligent colonists brought forth botanical gardens, such as those of Cape Town and Mauritius, which were replicated in other tropical colonies. Meanwhile, Europeans were exposed to strange diseases whose cures were often found in local plants. Interaction with the native peoples of these lands resulted in the absorption of the knowledge of indigenous pharmacopoeia into the European corpus through translations and compilations (Grove 1995). From the disasters of early colonization arose the habitus of conservation and an appreciation of tropical plant knowledge.

By the mid-nineteenth century, colonial botanical gardens were producing economically valuable knowledge in a form that made them the equivalent of the industrial research laboratories of today (Brockway 1979). Cinchona for quinine and *Hevea brasiliensis* (Brazilian rubber) for rubber were some of the triumphs of the network of collectors conveying plants to centers of calculation such as the Royal Botanical Gardens in Kew, England, from which the seeds were dispersed to parts further afield for imperial cultivation. Such power came to shape the worldviews of colonial rulers. In *Nature's Government*, historian Richard Drayton noted that since the end of the eighteenth century, Europeans believed that they possessed a mastery of nature that would deliver the "greatest good on the greatest number" (Drayton 2000, xv). From merely coping with the maladies and trials of the exotic world, European practitioners refined their techniques and methods to the point where they could confidently aim to accomplish speculative goals, such as the domestication of *Hevea* in Malaya.

Until the end of the nineteenth century, imperial plant sciences were built on a string of botanical gardens in various colonies. Within the British Empire, the gardens at Cape Town, Mauritius, Calcutta, and Peradeniya in Ceylon played important roles in plant transfer and acclimatization. These processes operated in a semiformal network centered on Kew. Under the direction of energetic leaders, such as Joseph Banks, William and Joseph Hooker, and William Thistleton-Dyer, programs were launched for obtaining economically important plants from non-British territories for transfer to sites under British control, with climates prospectively suited to their growth. The transfer of *Hevea Brasiliensis* to Malaya (Brockway 1979; Grove 1995; Drayton 2000; Barnard 2016) was one such successful venture.

By the beginning of the twentieth century, two major developments in the plant sciences had reshaped the practice of plant research in the colonial world. The first development was the rise of genetics. The term "genetics" was coined by William Bateson, who conducted research at Cambridge University, at the time when the papers written by Gregor Mendel in 1865 and largely neglected until the turn of the century reemerged (Olby 1987; Richmond 2001). With the new science in hand, plants could be bred for desired characteristics with greater precision. This development slotted into an already well-established tradition of research on plants with economic value to industrial Europe, but at the same time the institutional structure for this research was also evolving, resulting in the second salient development: in 1898, the establishment of the Imperial Department of Agriculture in Barbados heralded a shift in organization models away from the botanical garden toward departments of agriculture closely tied to the bureaucracy of the colonial state (Worboys 1979).

Scholars who have studied the history of the sciences in colonies have questioned the relevance of a distinct field of colonial science. Historian Lewis Pyenson has stated that "a sophisticated, agricultural-experimentation station in a colony may contribute to botanical knowledge, but its purpose is to advance local production and export" (1989, xiv). For that reason, he believes that studies of colonial science should avoid the taint of becoming too entangled in the colonial political and economic order by redirecting attention to the "exact" (physical) sciences. In a related vein, historian Helen Tilley argues that there is no "colonial science" as such, because Western science did not develop in isolation from the rest of the world, nor did the sciences in the colonies. On that basis, there is no essence of colonial science that sets it apart from any other widely recognized form of science (Tilley 2011, 10–11).

An underlying tension exists in this field concerning whether the empirical reality of science, being about the one nature shared by all nations and peoples, should define studies such as this. In this article, I present a case that demonstrates how sociopolitical arrangements within which colonial science was undertaken produced political economic structures that were distinctly colonial.

I begin with a discussion of the ways of seeing that modern states adopted, which in colonial sites produced and reproduced ideas of colonial supremacy. I then proceed to the case of Taiwan, a colonial site where the intensive application of plant sciences in the first half of the twentieth century transformed rice cultivation and enabled farmers to produce the round-grain rice preferred by Japanese consumers. Once this was accomplished, Taiwan was directed by its Japanese rulers to embrace the raison d'être of a rice colony. Taiwan's scientific expertise was applied to the new territories falling World War, the expertise acquired by Japanese scientists in shaping Taiwanese rice cultivation was redirected toward the postwar pro-American order in Asia, now under the patronage and support of the United States.

From the perspective of the historical actors, the colonial nature of the polities where they served determined which sciences would proceed, which would be sidelined, and how research would be practiced. Over time, the dichotomization of the world between the advanced and the colonized is indispensable to understanding science outside the Euro-American "West" as colonies evolved into developing nations.

## COLONIAL IDEOLOGY AND SCIENCE

The concept of "coloniality" refers to a state of consciousness that divides the world between the West and the non-West and confers the leadership of the global order to the former. During the colonial era (from the 1500s to the 1960s), a global division of labor placed important industries and decision making in the realm of the West while assigning the work of extracting natural resources, sometimes through slavery or indenture, to what we now call the Global South (Quijano 2000, 538). The dominance of Western power was asserted through colonial capital. This colonial capital achieved supremacy by displacing other economic systems, such as the trade networks of the Malay world and the cloth producers of South Asia, often through violent and coercive means. Yet over time the coercive process was elided. Syed Hussein Alatas argues that colonial power conferred the status of superiority to the Western powers and their civilizations. Europeans, in turn, came to perceive the people subjugated to their rule as indolent and lacking in industry and creativity within the capitalist world system (Alatas 1977; Baber 1998).

In an essay titled "The Question Concerning Technology," the German philosopher Martin Heidegger noted that, upon attaining greater knowledge about nature, human societies expected technology to deliver products from nature with surer predictability. No longer were producers content to leave resource extraction to the vagaries of chance and nature; production techniques would "challenge nature" to yield its value on demand, on the basis of calculated formulae and standardized methods of observation (Heidegger 1993; Scott 1998). Combined with Alatas's argument, I propose that technoscience became another tool in the kit for colonial supremacy, as its track record of past success became justification for further pursuit along the same lines.

Colonial science could be deployed to enhance both the material and symbolic power of the colonizer. For example, the meteorological service reflected Japanese power on the Korean peninsula. Beginning as a rudimentary network of observation stations serving the Japanese military during the Russo-Japanese War of 1904–1905, the meteorological service expanded to improve agricultural efficiency after colonization. It also symbolically displaced the Royal Observatory of the Korean Kings, thereby buttressing the ideology of Japanese imperial hegemony (Miyagawa 2008). Corresponding developments in Taiwan enmeshed the island colony with the peninsular colony and the home islands (Zaiki 2007). Similarly, in the field of agriculture the Japanese in Korea established an agricultural experiment station in Suwon and nurtured indigenous agronomists who became the first generation of rice experts in the independent Republic of Korea (Kim 2018, 191).

Colonial ideology provided both solution and justification for Japanese rule on Taiwan. Administrators in Taiwan explicitly tied coloniality and science together in a social-Darwinist approach to developing and controlling the island colony. A statement by Goto Shinpei, the Civil Administrator of the Government-General of Taiwan from 1898 to 1906, provides insight:

> Any scheme of colonial administration, given the present advances in science, should be based on principles of Biology. What are these principles? They are to promote science, and to develop agriculture, industry, sanitation, education, communications and police force. If these are satisfactorily accomplished, we will be able to preserve in the struggle for survival and win the struggle for the "survival of the fittest." (Yao 2006, 45)

Research aimed at revealing the nature of Taiwan—not only its geology, fauna, flora, and meteorology, but also its society—was the key to success for what was, at the beginning of Shinpei's tenure, a struggling colony. Previously, Taiwan had been a drain on Japanese finances due to the military operations launched to pacify the island. Continued colonization was proving unpopular, and there were even calls among the Japanese public to give it up. Shinpei determined to turn around the colony's finances so that it would earn a surplus instead of draining subsidies from the central government. On March 22, 1899, Shinpei obtained a bond issue of 35 million yen; as a result, development expenditures overtook administrative costs, making up 68 percent of the total government costs in the period 1899–1905. The application of these funds generated revenues that were used to repay the debt. One key initiative was to conduct a land survey that enabled the government to collect property taxes efficiently. This survey confirmed the native Taiwanese tenants' possession of the land they farmed and, as a result, expansive plantations under the ownership of colonial capitalists did not become a feature in Taiwan (Ka 1995, 51–52). Large plantations did not develop, because Japanese firms simply purchased the harvests from the farmers (Grajdanzev 1942, 61).

In 1903, the government began the process of rationalizing the varieties of rice planted in Taiwan. Starting with a total of 1,197 local varieties, the government restricted the allowed varieties to just 375, and each village was permitted to select only three varieties. According to Kim Tae-Ho, a similar pattern of coercion existed in Korea under Japanese rule (Kim 2019).[1] The government then planted the three varieties to yield seeds over four years, and when the desired seed supply was available, it was handed to the farmers (Mendiola 1949, 76). This process eliminated lower-yielding local varieties while retaining those with higher yields (Mendiola 1949, 77). However, while the increased output of Taiwanese varieties supplied exports to Japan, the rice did not fetch a high price there. After Horai rice was successfully cultivated, Taiwanese farmers could sell it for a higher price than Taiwanese varieties in the main islands, though it was not as expensive as rice grown on the Japanese home islands (Grajdanzev 1942, 53).

Institutional arrangements for rice research were constructed to advance rice-breeding. In 1902, following the end of military action to pacify the island, governors from the districts of Taiwan held a meeting to discuss the development of the economy, including the topic of experimental farms.

These discussions led to the establishment later that year of the first experiment station, which eventually employed Eikichi Iso, in 1912.

Although the experimental farms demonstrated the colonial state's commitment to progress, Japanese-ruled Taiwan cannot be mistaken for a liberal nation-state. For example, the Imperial University of Taihoku, with which Iso was affiliated, was all but closed to Taiwanese students. Taiwanese students who sought higher education often went to Japan, because the institutions in their homeland were exclusively for Japanese students (Tsurumi 1977). Despite being a state that was nominally committed to supporting Japanese capital, Taiwan's rulers did not completely trust their compatriot businessmen to be responsible stewards of the island's resources. In forestry, for example, the state chose to invest directly in commercial forestry operations to exploit forests scientifically and sustainably (Hung 2015). It is within this context—a financially solvent colonial state with an active posture toward science—that Iso came to Taiwan to conduct his rice-breeding experiments.

## THE SCIENCE THAT NURTURED HORAI RICE IN TAIWAN

Eikichi Iso represented the breed of technical experts who would make the Japanese Empire modern and productive. He graduated in 1911 from what was then the Tohoku Imperial University Faculty of Agriculture in Sapporo (renamed Hokkaido Imperial University in 1918) and arrived in Taiwan in 1912, initially at the Government Experimental Farm in Taihoku. In 1915, working in Taichung, a research team including Iso developed the Taichu No. 65 variety of rice, which was a milestone in the development of Horai rice (see figure 1).[2] Horai was the name given to the round-grain rice bred from crosses of Japonica and other varieties grown in Taiwan. In 1919 and 1920, the Government-General sent Iso to Cornell University in Ithaca, New York, under appointment as an overseas investigator. There Iso studied plant breeding and biological statistics under the supervision of Professor Harry H. Love.

At this time, the United States saw the emergence of new knowledge about photoperiodism, the effect of light exposure on the development of plants—findings that had an impact on agriculture. Photoperiodism was discovered as the result of the experimental work of W. W. Garner and H. A.

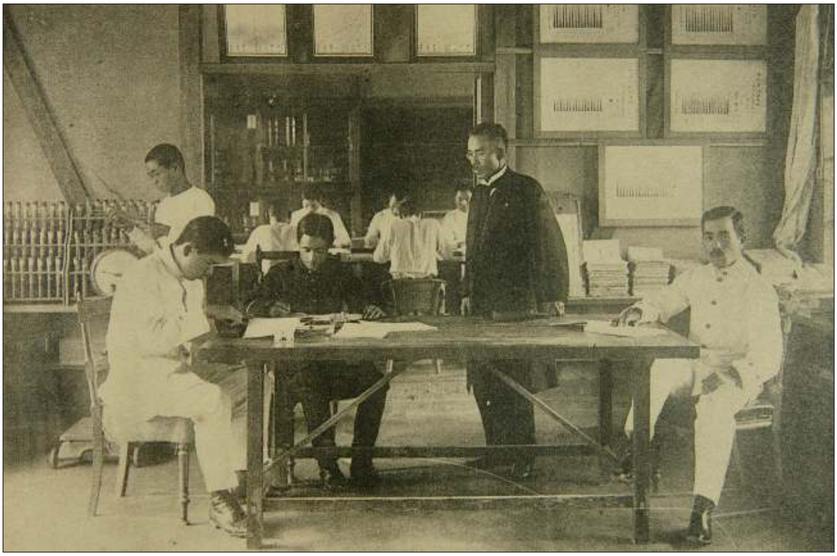

FIGURE 1. Eikichi Iso, seated at right, together with research associates at an agricultural research laboratory in Taichung, Taiwan. *Source*: Used by permission of the NTU Eikichi Memorial House.

Allard, two scientists from the U.S. Department of Agriculture. According to Garner and Allard, the effect of light upon plants could be measured in three ways—intensity; quality, or wavelength of radiation; and the duration of exposure (Garner and Allard 1920, 553). Their focus was on duration of exposure, for it appeared that plants could grow optimally with less than full-strength daylight, whereas experiments with different rays from different parts of the spectrum, such as ultraviolet, yielded indeterminate results. Garner and Allard also systematically eliminated factors such as water and temperature by means of other experiments.

Photoperiodism influenced Iso in his search for solutions for rice-breeding problems in Taiwan. He was at Cornell when this discovery came to light, and the papers published by Garner and Allard were available at the University of Taihoku, where Iso worked. Iso identified the ways in which photoperiodism influenced the spread of rice cultivation to Japan. His research into the origins of Japonica varieties traced them to three basic pedigrees: *Hyuga* or *Kasasa*, *Izumo*, and *Koshi*. Iso observed that in the three

Japanese provinces of San-in, Kyushu, and Hokuriku, the rice grown could be traced to these three pedigrees (Iso 1954, 106–107). He theorized that the spread of varieties in Japan had been possible whenever the day-length (hours of exposure to daylight in a day) and temperature of the newly cultivated region matched that of the region of origin. Although the precise routes and periodicity of transmission could not be reconstructed, the fact that the three basic pedigrees were widespread gave evidence to a diffusion of cultivation from the earliest site to the latest. As Iso explained, through "the long natural and artificial selection" process, involving "mixing, natural hybridizations, segregations and recombinations" over centuries, "present varieties must have been constructed" (Iso 1954, 107).

If that was indeed the history of rice in Japan, might it not be the pathway for adapting Japonica varieties to Taiwan? "There is an indication in the rice plant that the action of its heading and ripening accelerates as the length of day becomes short," began Iso's description of the response of varieties of rice to different day-length conditions (Iso 1954, 57). Applied to Taiwan, for example, the native varieties planted in the first crop would be weak in response to day-length and temperature. The dates when the tips of the rice plants, known as heads, began to emerge were recorded as the date each variety began heading. These varieties would be planted when the day-length is short and temperature relatively low in the early part of the year, and would begin heading in June when the day-length is long (13.16–13.65 hours) and temperature high (26.6–27.3 degrees Celsius, or 79.88–81.14 Fahrenheit). By contrast, varieties chosen for the second crop would have a strong response to day-length and temperature and begin heading later in the year when there would be only 11.52–12.25 hours of daylight (Iso 1954, 58). Thus, the territory of Taiwan and the planting materials could be rationalized, mapping latitude to day-length, and genes to appropriate day-length and temperatures.[3]

Through this process of experimentation, Iso succeeded in producing Horai rice. The word *horai* 蓬莱 was a neologism coined to name a new creation (in Mandarin Chinese, it was *penglai*; in vernacular Taiwanese, *ponlai*). In the shared mythology of the Japanese and Chinese cultures, the term refers to a paradisiacal mountain. Fittingly, Horai was also an archaic Japanese name for the island of Taiwan (Fujihara 2018, 143). It should be noted that Horai did not specify a particular breed or crossbreed of rice; in fact, as a category it was a collection of many glutinous and non-glutinous types (Iso 1947, 92). Promising candidates were tested and further crossed with other varieties selected for desirable traits. This continuous process was designed to bring out recessive traits, as well as to transmit known traits evident in the phenotype of the variety being crossed (Iso 1954, 132–133). These varieties were tested in different locations based on qualities that suggested a particular variety was well suited to its test location.

For Taiwanese rice to sell on the Japanese market, a length-breadth ratio of 1.6 was required. With this success, Taiwan became a rice producer for the Japanese home islands. It also caused significant changes in the island colony's economic position within the empire and subsequently affected the political viewpoint of the colonial rulers of Taiwan.

## HORAI CULTIVATION TRANSFORMS TAIWAN

Technical advancement in the form of greater rice yields was a self-evident good in Eikichi Iso's opinion, and scientific breeding had spread this boon to the Taiwanese farmer. The outstanding Horai variety was Taichu No. 65. It was grown across the entire island, unlike many others, which were designated for specific places. The acreage for Taichu No. 65 was 246,349 *ko* (238,958 hectares, about 590,478 acres) in 1936. This was a cross of two Japanese varieties, *Kameji* and *Shinriki*, the original crossbreeding of which was performed in 1923 (Iso 1954, 133–136). Taichu No. 65 also became a popular parent for further crossbred varieties. Farmers voluntarily attempted to try growing rice of even better yield and quality than the Taichu No. 65 that had become symbolic of Horai. "They were so willing to do this because they were ambitious to have their own varieties named with local description in the foreign market," explained Iso (1954, 136).

Horai gave an increase in yield of 2.5 to 4.4 times over indigenous *chailai* varieties of rice. But production costs for the former were also higher: 342 yen per *ko* for Horai over 223.8 yen for *chailai*. Some of these expenses came from the cost of access to irrigation and chemical fertilizers, which had to be used instead of manure due to the short nursery period. Products that used to be grown by the farmer now had to be bought for cash. As noted by historian Andrew Grajdanzev, "the expansion of area under Horai is therefore not so much a sign of prosperity, as it would at first sight appear, as a sign of the growing need of the farmer to pay taxes, to pay for irrigation, and to pay for the tobacco which he formerly produced himself (and is now a state monopoly)" (1942, 55).

The nature of colonial technological improvement was to enmesh farmers more tightly within the structure of the colonial economy. Cash-based transactions, credit to facilitate the higher cost of production, dependence on physical infrastructure such as irrigation and transportation, and penetration by technical extension officers and researchers such as Iso transformed agricultural practice. The calendar of the Taiwanese rice farmer became synchronized with that of the Japanese, for the first harvest of Horai between June and October relieved food shortages in the home islands as it was a winter crop that could not be grown in the harsher climate of more northerly latitudes (Ka 1995, 168).

Horai cultivation upset the colonial political economy by initially benefiting native Taiwanese farmers at some expense to Japanese-owned sugar factories. Japanese capital chased after investment opportunities outside the home islands from the 1910s onward, as profits declined at home. The Taiwanese sugar industry offered such opportunities, but there were barriers to entry. Locally owned mills competed intensely for raw cane and drove prices high in 1904 and 1905. This competition changed under new regulations. In 1905, all cane-growing farmers were required to sell their produce exclusively to a designated sugar factory in their respective area. In addition, the opening of new mills was subject to government approval, thus preventing Taiwanese producers from expanding (Ka 1995, 79).

The pricing mechanism for cane was regulated to favor Japanese sugar factories. Prior to Japanese rule, a sugar-sharing system operated such that a portion of sugar was returned to the farmer after deducting the cost of processing. After colonization, this payment in kind was changed to cash payment. The imposition of regulations known as "measures for balancing the price between rice and sugar" established a new price-setting mechanism. Instead of linking the price of cane to sugar, mills now paid farmers an amount that was based on rice prices instead. At the time, rice was *chailai*, the Indica varieties primarily consumed locally (Ka 1995, 115).

In 1918, rice riots in Japan highlighted the importance of food supplies as Japan underwent social changes due to industrialization and urbanization. Government policy began to favor importation of rice from the colonies of

Taiwan and Korea (Ka 1995, 134). This policy change coincided with the successful breeding of Horai rice, which put Taiwan in a position to satisfy Japanese consumers. The rice buyers operated as competitive firms, unlike the sugar factories, which were monopsony buyers protected by the state. As a result, Horai prices rose and attracted more farmers to switch from *chailai*. These conditions depressed the supply of *chailai* just when demand for it rose, because the Horai farmers were selling their crops for export and needed *chailai* rice for their own consumption (Ka 1995, 139).

Because the pricing mechanism for cane purchase was based on *chailai* prices, after 1925 the factories had to pay more for their raw materials. As the price of rice rose, farmers shifted away from cane farming, thus reducing supply for the sugar factories (Ka 1995, 161). As a consequence, Taiwan became less attractive as a site of investment for Japanese capital. Disputes between farmers and factory owners over the price of sugar were frequent, but the factory owners sustained the practice of buying from farmers instead of running their own plantations, as this was more profitable under the regime enforced in the colony (Grajdanzev 1942, 61).

The farmers exercised their agency in the degree of investment that they applied to their fields. Economists Elliott Fan and Shu-jen Yeh note, for example, that more secure tenancy encouraged farmers to invest in irrigation facilities but at the same time were not induced to increase fertilizer use; fertilizers did not have a long-term effect on output, resulting in an indifference to application of that input under the secure tenancy arrangement (Fan and Yeh 2017, 14). Thus, farmers in colonial Taiwan could exercise their agency in response to state policy.

The Japanese capitalists sought government assistance to curtail the increase in rice prices and production. Although the Government-General had usually helped the sugar industry, the geopolitical situation was changing as crop failures in Japan and war in the later 1930s altered the balance of interests in the metropolis. The Government-General desired a policy that would both secure sufficient rice production and ensure low prices (Ka 1995, 163–165). The implementation of a government monopoly of the Taiwanese rice trade coincided with a 13-percent drop in the price of rice in 1939. This drop may have helped the sugar producers, but it also necessitated a state intervention to stabilize a society in the midst of a turbulent period in world affairs.

The entrance of an alternative commodity crop with a ready market in Japan unbalanced the calibrated mechanisms in place in Taiwan to boost the sugar manufacturers' profits. The Government-General faced the arduous task of keeping sugar producers' profits high while ensuring that the native smallholding farms were not driven to ruin. As Japan's home islands increasingly came to rely on rice imports, the state also had the added task of ensuring stable supplies of rice to the home islands without allowing prices to skyrocket. In this way, Horai came to occupy an important position in the Taiwanese Government-General's perspective, as it identified itself as a rice colony.

## A TAIWANESE SUBEMPIRE BUILT ON RICE EXPERTISE

Tropicality was a central feature of Taiwan in the eyes of Japan. Taiwan's climate made it an ideal site for sugar cultivation. The production of sugar alleviated the balance of Japan's trade deficit. In the earlier phases of colonization, Taiwan had been seen as a site of curiosities to be studied scientifically in order to make it function as part of the growing Japanese polity. This ideological setting, guided by the "principles of Biology" in Goto Shinpei's words, was the site of Eikichi Iso's experiments to breed Japanese varieties of rice. The success of breeding rice, together with that of the more established crop of cane, gave Taiwan an identity as a producer of commodities for the Japanese imperial economy. As the Japanese Empire expanded, Taiwan's perceived specialism in tropical agriculture translated into a "subimperial sphere of influence in South China and Southeast Asia" for the Government-General (Schneider 1998, i).

The vehicle for the fulfillment of these subimperial ambitions was the Taiwan Development Corporation (1936–1946) owned by the Government-General of Taiwan and engaged primarily in mining activities in Indochina and agriculture in Hainan. In Japanese, this entity was known as *Taiwan Takushoku Kabushiki Kaisha*, or Taitaku. Owned and supported by the government of Taiwan, Taitaku was a business that competed with other Japanese firms, whether privately owned or state-controlled, with the goal of inducing industrialization in Taiwan through the benefit of an economic hinterland carved out of the new territories conquered by the Japanese military in Asia (Schneider 1998, i).

Subimperialism implied that the colony emerging as the sub-metropolis had interests of its own, distinct from the metropolis, and had the means to protect and expand its powers even within a relationship that was formally dependent upon the metropolis. The Government-General found itself in a stronger position when it was no longer dependent on subsidies after 1905. The developmental agenda of building irrigation and transport links and funding agricultural research could be pursued through its own means. The success of Horai as an export commodity to Japan demonstrated the potential for technoscientific development to disrupt Taiwan's terms of trade with the mother country. In short, Taiwan was acquiring political agency as a result of scientific research capabilities.

The draft plan for a "Taiwan Development and Industrial Corporation" prepared in 1919 for Governor-General Akashi Motojiro was an early proposal for a state-financed corporation for development purposes. Its aim was to provide financing for land development projects too difficult for private firms to undertake, and to be involved in projects around South China and Southeast Asia (Schneider 1998, 34). This basic concept was discussed until 1936.

Commentators noted that research about the region would be essential to Taiwan's interests. A 1922 article in the *Taiwan Review* (*Taiwan jiho*), the official organ of the Government-General, called for a tropical research institute to conduct economic and commercial information-gathering and scientific research. The next year, another article called for the establishment of an economic research unit in the Government-General that would have its own commercial officers posted at Japanese consulates in South China and Southeast Asia. (Schneider 1998, 34). Goto Shinpei's policy aim—to accumulate data for more effective control—was now training the gaze of the Japanese in Taiwan beyond the island's shores.

For a time, the confluence of opposing factors prevented the establishment of such an organization. These factors might be parties with contesting interests or an unfavorable economic climate. Factors in favor of this organization finally aligned around 1935 as both the Colonial Ministry and the Government-General of Taiwan developed reasons to rally around the concept. For the Colonial Ministry, established in 1929, such a project would give it greater visibility and influence in policy. At the time, its actual powers were limited due to competing ministries with different spheres of influence, such as the military's control of affairs in Manchuria, and also because the Governments-General of Korea and Taiwan had substantial autonomy (Schneider 1998, 48). By 1936, there was talk of scrapping the ministry altogether.

In 1935, the Government-General held a "Tropical Industry Research Conference" in conjunction with the fortieth anniversary of Taiwan's colonization by Japan. For Taiwan, the conference was an opportunity to publicize the achievements in economic development on the island colony (Schneider 1998, 50). At the conference, Governor-General Nakagawa Kenzo raised the concept of a *nanshin*, or southern sphere of influence, that Taiwan and the Ministry of Colonial Affairs would jointly develop. This was to be the next logical step following the rapid development of Taiwan under Japanese rule, one that would connect the rich resources of South China and Southeast Asia to the industrializing sub-metropolis of Taiwan.

In Taiwan itself, the company engaged in land management, chemical manufacturing, and forestry. The company was started with the Government-General's contribution of 15,000 *ko* (14,550 hectares, or 35,954 acres) of land and an issue of the shares not held by the state that raised 3.75 million yen, mostly from Japanese companies and Japanese individuals (Schneider 1998, 69–71). Outside the island colony, the major projects undertaken by Taitaku were iron mining in Indochina starting in 1937, which expanded to other minerals such as nickel and phosphate in 1941 (Schneider 1998, 197), and agricultural production on the island of Hainan. Other projects included jute production in Indochina, forestry in the Andaman Islands, and other agricultural production in the Dutch East Indies and the Philippines. The mining activities were meant to provide raw materials for the development of Taiwanese metal industries, while rice farming especially would take advantage of the experience gained from the development of Taiwan itself.

Hainan was meant to become a "second Taiwan" through Taitaku's program of development (Schneider 1998, 230). After the Japanese Navy seized the island in February 1939, the intention was to transform it into a colony of Japan, much like Taiwan. One problem was that Hainan was a rice importer, as its agriculture and communications infrastructures were not developed enough to support a productive rice-farming sector. Hainan's geographical location was of strategic importance to the navy, so food security was an added incentive to develop its agricultural capacity.

Taitaku had already outlined a plan for agriculture in Hainan before the occupation proper began. Food and other crops expected to be readily profitable were prioritized. Land would be acquired and thence leased to tenant farmers, reflecting Taitaku's own function as a major landlord in Taiwan. Taitaku operated on the basis of experimentation and localization first; it had its own nurseries for producing seeds for distribution to Japanese military units located near each nursery (Schneider 1998, 252–253).

Horai rice proved to be a qualified success in Hainan. Although its introduction did increase output significantly, wartime conditions meant that supplies of fertilizer were limited. Further, it required the tenant farmers to follow the same techniques practiced in Taiwan. In 1940, the first experimental plantings showed that certain Horai varieties yielded two to three times that of indigenous Hainanese rice. Under actual production conditions, however, only the fields directly managed by Taitaku produced the superior yields expected of Horai crops (Schneider 1998, 257).

The "invention" of Horai rice provided a sense of mission to the administrative class of the Government-General, creating a new identity for Taiwan as a rice colony. Although domestic tensions arose from conflicts between sugar producers and farmers, and the need to protect Japanese capitalist interests through price controls, the aspect of Taiwan facing the rest of the empire was that of a rice colony, developed through assiduous investments in scientific research, land reclamation, and irrigation works. Policy framing and the definition of the Government-General's interests in the expanding empire were focused on its proclaimed expertise in rice production.

## APPLYING TAIWANESE RICE KNOWLEDGE TO ASIA

After mastering rice-breeding in Taiwan, Eikichi Iso was able to apply this knowledge to similar ventures in other parts of Asia. A common theme in his descriptions of rice regions encompassed the two fundamentals, variety type and day-length. When trained upon China, his insights highlighted the similarities between the mainland and Japan, mapping both varieties and geographies to read the unfamiliar Chinese mainland through referents from the Japanese main islands.

According to Iso, Chinese rice was of the *Hsien* and *Keng* non-glutinous varieties, respectively Indica and Japonica domesticated in Taiwan before

Japanese rule. Taiwan also had varieties of glutinous rice called *Nuo*, with both Indica *Nuo* and Japonica *Nuo* types. Whereas in Japan there were only Japonica varieties of rice, those in China were mostly Indica. In Japan, non-glutinous varieties were *Uruchi*, while glutinous ones were called *Mochi*. With reference to rice-growing in Kiangsu and Chekiang, Iso noted that the varieties in these parts of China had a response to "light and temperature" similar to that demonstrated by varieties grown in Kyushu and the southern parts of central Japan. As a result, experimental plantings of "*Shinriki*, a Japanese variety" grew well in Hangchow (Iso 1954, 76).

It is worth noting that *Shinriki* was a parent to the popular Taichu No. 65 Horai variety. Its introduction thus represented the scientific prospecting of territory on which Japan had designs. Just as finding ecological niches conducive to Japanese rice had made Taiwan a successful rice-producing colony, matching new territory to Taiwanese regions could perform the same role as Japanese rule extended to more of the mainland.

In addition to the Government-General's designs on mainland China, plans for southward expansion also posed technical challenges to the Japanese imperial rice scientist. The farther south the latitude of a region was with respect to Kyushu, the harder it was to recreate conditions suitable for varieties of rice familiar to the Japanese. Two technical approaches could be attempted. In the first approach, the period in the nursery would be reduced to the extreme through the use of fertilizers in order to take full advantage of the short day-length in the southern latitudes that promoted the growth and development of Japanese varieties. In the second approach, varieties less sensitive to day-length and temperature would need to be developed, possibly through crossbreeding with Japanese varieties in a repetition of the process through which Horai had been conceived.

From the sub-metropolis of Taiwan, Iso's base in Taihoku became a center of calculation and collecting data from various parts of Asia, including the Japanese home islands. The harvest of the first Taiwanese crop arrived in Japan in time to alleviate shortages, because Japan could not sow its own rice during its harsh winter. For example, on pages 77–79 of his book, *Rice Crops in Its* [sic] *Rotation in Subtropical Zones* (1954),Iso presented "The recommended varieties of the rice plant in China" and "Temperature, rainfall, humidity & days free of frost in the agricultural regions of China." On page 124, a table showing "Day-length & Temperature of Hokkaido & the First

Crop Season of Taiwan" noted the asynchronous crop cycle between these two Japanese territories at the extreme latitudes of the pre-1937 empire, with the Hokkaido crop being sown in April–May and the Taiwan crop in January, and ready to harvest in September–October and June, respectively.

Limited capital was a constraint in the colonization schemes of Imperial Japan. As the empire expanded into the mainland after 1937, this issue became ever more severe. The struggle to transform Hainan into a "Second Taiwan" serves as a cautionary example. In addition to the failure to spread the cultivation of Horai island-wide, despite initial success at the Taitaku-farmed nurseries on Hainan, development plans were hindered by shortages of such basic resources as trucks. No doubt, war conditions worsened such problems, but even under the relative peace of the prewar period, Taiwanese development was not lavishly capital-intensive. Agriculture remained highly manual and made use of basic equipment that was handcrafted rather than mass-produced. These "traditional" implements operated in conjunction with chemical fertilizers and precise timing and irrigation to present a model colonial agricultural system that was a hybrid of technoscience and preindustrial craft.

It should come as no surprise, then, that Iso's observations of Southeast Asian rice-culturing methods paid close attention to the craft aspects of their agriculture. For example, Iso noted that in Malaya "a peculiar seed-bed and transplanting" method was in use. This method, a floating nursery, was implemented because the rice-planting districts were very well watered. This nursery was made by laying thick mud on piled rush grass to make a bed for the seedlings. As more water entered the field, more grass or straw was piled underneath to further elevate the seedbed. The seedlings were transplanted twice into secondary nurseries so that the total period in the nursery was from 60 to 90 days, far longer than the practice in Taiwan (Iso 1954, 161). This type of knowledge was essential as the extreme rainfall of monsoon regions coupled with winterless years presented unknown challenges to Japanese imperial scientists. Their experience with Taiwan, where a hybrid approach adapted traditional techniques to harness the benefits of modern breeds and infrastructure, meant that they expected to derive value from absorbing knowledge about various forms of indigenous agriculture.

Japanese imperial agriculture in the period from the 1930s to 1945 did not feature mechanization, so the particular methods of agriculture adapted to environments in Southeast Asia continued much as they had before Japanese rule. In a very different situation at a later stage of development in the 1970s, World Bank financing eventually extended the use of tractors and combine harvesters to Malaysia, along with other parts of Southeast Asia, and created significant inequalities of access to capital and opportunity.[4]

Iso's "anthropological approach" to explaining agricultural practices was a function of the limits of modern Japanese imperial agriculture. It was understood that Japan, being unable to afford methods that could more effectively dominate the terrain, would have an approach of limited modernity still dependent on human and animal power and making use of homemade straw and wood implements for some functions instead of factory-made tools. However, Japan's approach was a practical modernity that delivered on what counted the most: yields and productivity. This simple mantra of progress was the essence of colonial science. As long as this practice delivered substantial improvements, it was not invalidated by the compromises that it had to make with respect to capital.

## FROM IMPERIAL RICE RESEARCH TO POSTWAR INTERNATIONAL COOPERATION

After the war, Japanese technocrats sought to translate the experience of developing Horai into a roadmap for Asian agricultural development. A compilation of the technical and institutional history of Japanese rice research, *A Century of Agricultural Growth in Japan: Its Relevance to Asian Development*, was meant to demonstrate how this could be accomplished. The preface states that the book's purpose is to provide "a positive economic analysis of the long-term growth of Japanese agriculture" in order to "facilitate a correct understanding of the nature and magnitude of the problems of agricultural development in Asia today" (Hayami et al. 1975, xv). The book focuses primarily on the experience of rice research and the development of its cultivation in Japan proper from the beginning of the Meiji Restoration to the mid-1970s. Featured topics include economic trend data, a chronology of institutions founded for rice research and extension in Japan, and evaluations of the impact of technology, infrastructure, and rice-breeding research. It is noteworthy that only in the concluding chapter is the colonial experience in Taiwan explicitly highlighted as a possible Japanese contribution to rice agriculture in Asia.

The authors classify the technological changes brought by Japanese colonial rule to Taiwan and Korea as "land-saving" and describe them as a transplantation of methods that had been developed in Meiji Japan: the changes took the form of "local adaptation of a technology of Japanese origin (embodied typically in improved seeds)" and "investment in irrigation facilities as a prerequisite for the diffusion of the new technology" (Hayami et al. 1975, 204). The book goes on to note that, as land was plentiful in the Philippines until about 1960, production could be increased through reclaiming new land. However, as the frontier closed, the land-saving technologies mentioned became increasingly relevant to the Philippines' needs (Hayami et al. 1975, 204).

As explained in this book, the introduction of Horai varieties in Taiwan met with a bottleneck as irrigation facilities were well developed only in parts of Taiwan and progressedover time as the irrigation system expanded under colonial development schemes. The authors state, "It appears that the construction of the irrigation system in Taiwan was, to a large extent, induced by the profitability of such investments which was increased by the technological breakthrough" of Horai (Hayami et al. 1975, 213–214). The lesson here is that agricultural development was a system and not a collection of disparate projects. The essential catalyst in this case was a planting material with a substantial and lucrative market, which in turn needed to be backed by the support of products such as fertilizers, and by infrastructures for irrigation and transportation. In this sense, we could consider rice-breeding research a means of achieving unbalanced growth, as advancement in one sector dragged others forward, as described by economist Albert O. Hirschman (1958).

It would seem natural, then, that Yujiro Hayami, the lead author and editor of *A Century of Agricultural Growth in Japan*, was based in the Philippines, at the International Rice Research Institute (IRRI) in Los Baños. The IRRI was a long-term research program initially funded by the Ford Foundation and the Rockefeller Foundation dedicated to research on high-yield rice breeds. The Japanese connection was essential to the operations of the IRRI. For example, a bibliography of translated rice-research articles in the possession of the IRRI in 1975 noted that, other than English, the language in which most articles were published was Japanese. In order to make the information in these articles accessible, a branch of the IRRI Library and

Documentation Center was established in Tokyo to produce translations (Malagayo-Alluri 1976, 2).

The previous section recounted the Japanese experience of bringing rice agriculture to Hainan with less-than-impressive results under the constraints of war. After the Second World War, the perception that Japan was the torchbearer of rice research for the rest of Asia was reconfigured under a new political order, because Japan was in alliance with the United States and had access to its capital. No longer aimed at exploiting land to support an exclusive clique of Japanese capitalists, the research entered an era of international cooperation with friendly nations aligned with the Western bloc during the Cold War.

The means remained the same as before: better-yielding planting materials backed by the right supplies of fertilizers and irrigation water, and access to profitable markets. And with figures like Eikichi Iso continuing a career that touched upon Taiwan and parts of Southeast Asia, the people who had been responsible for the successes of colonial Taiwanese rice research were actively involved in making a success of the postwar international rice-research order.[5]

## CONCLUSION

Between September 20 and November 11, 1944, a Philippine Agricultural Survey Commission visited Taiwan. Nemesio B. Mendiola conducted a study to "determine the methods of culture used, particularly what characteristics or features of the Taiwan rice culture had been responsible for the phenomenal progress it had made," and thence to adapt whatever was practical for conditions in the Philippines (Mendiola 1949, 41). Mendiola's language makes it apparent that Taiwan had made a name for itself as a rice-producing territory, and that this "phenomenal progress" could be credited to Japanese rule.

The tropicality of Taiwan, coupled with its precarious finances, presented a puzzle to its Japanese colonizers. How were they to transform Taiwan into an economically viable possession of their fledgling empire? Agriculture became a key part of the solution. But before agriculture could be reformed, the politics had to be set right. Goto Shinpei's commitment to transform Taiwan through "principles of Biology" led to the accumulation of capital and its direction toward productive applications. Agricultural research would serve to answer the question of how tropicality could benefit the colonizers and the capitalists in their ranks, and Horai rice would be one of its signal accomplishments. This progress could not be achieved was not achieved without friction, for first it had to get funded by a government faced with multiple demands and scarce treasure. Once undertaken, the impact of Horai cultivation upon the colonial economy was complicated and not beneficial to the capitalist class in a simple and direct manner.

The land survey and tax regime imposed by the Japanese confirmed tenant farmers in the possession of their land. As a result, sugar farming did not give rise to the large-scale farming that characterized the crop in the Caribbean and other colonial sites. Instead, the Japanese capitalists took control of the sugar factories and imposed terms of trade that exploited the farmers supplying them. Into this mix came Horai, a fruit of colonial state science. Even as it disrupted the state-imposed sugar-buying monopsony arrangements, it also became a source of strength for both the Government-General of Taiwan and the Japanese Empire as a whole.

Horai rice and the expertise required to produce it gave Taiwan a raison d'être as a rice colony. Taiwan supplied the Japanese home islands with rice during the months when they faced shortages due to the absence of a winter crop. The success of Horai led the Japanese rulers of Taiwan to envision setting up a "second Taiwan" on Hainan when that territory fell under Japanese occupation, though this scheme failed due to war conditions despite the limited successes achieved in areas tightly supervised by experienced personnel sent from Taiwan.

The expertise of mobile agents of science such as Eikichi Iso made the development of Horai rice possible. Embodying modern scientific knowledge obtained first from Hokkaido and then from Cornell, Iso imaginatively mapped Japanese conditions to the latitudes of Taiwan in order to devise ideal plans for matching Japonica types to various others based on likely success. The emerging understanding of photoperiodism, first identified by Garner and Allard, enabled Iso to focus on the response of rice plants to daylight hours in his efforts at selection.

Keeping pace with the expanding Japanese Empire of the 1930s and 1940s, Iso observed rice conditions far beyond Taiwan, in southern China, Indochina, Malaya, and Java. After the Second World War, deprived of its empire, Japan continued to operate as a guiding light for the development of rice science in Southeast Asia, but as a part of Pax Americana and with new headquarters at the IRRI in the Philippines funded by the Rockefeller Foundation and Ford Foundation.

WEI YI LEOW is a PhD candidate in the Comparative Asian Studies Programme, Faculty of Arts and Social Sciences, National University of Singapore. The author is most grateful for the critical and thoughtful comments provided by two anonymous *Cross-Currents* reviewers and the guest editors for this special edition, James Lin, Graeme Read, and Peter Thilly.

## NOTES

1. Tae-Ho Kim notes that Korean peasants were coerced into planting new varieties scientifically developed in Japan (2018, 191). The notable difference from Taiwan was that, because of the similarity in climate between the home islands and Korea, the tropical adaptation required in Taiwan was not necessary in Korea.
2. For Iso, see http://iso-house.agron.ntu.edu.tw/iso.html. Subsequent findings determined that the person most responsible for breeding Taichu No. 65 was Jin Suenaga: https://tw.appledaily.com/headline/daily/20131130/35474524/.
3. The vulnerability of rice plants to blast disease came about because of early growth. Japanese varieties grown on Taiwan matured too early when grown according to normal practice and transplanted at 40–60 days of age. Iso experimented by reducing the time that the seedling spent in the nursery to 20–30 days. This difference was the key to the success of Horai rice (Mendiola 1949a, 78). When a variety known as *Nakamura* developed fast and headed early under the short-day (wintery) conditions, it was exposed to conditions ideal for the fungus-caused blast disease. By comparison, the blast-resistant varieties developed more slowly and, as a result, passed the period when the climate was most conducive to the disease without being exposed to it. *Iyosengoku* had a date of first heading of June 16; it was May 29 for *Nakamura*, June 20 for *Yokichisen*, and June 9 for *Aikawa* (Iso 1954, 113–114).
4. Political scientist James C. Scott's *Weapons of the Weak* (1985) provides an account of some of the changes brought by mechanization in rice farms in Kedah, Northern Peninsular Malaysia.

5. Iso did not agree to participate directly in IRRI research efforts. He preferred a "grounded" approach working closely with farmers, as he had done in Taiwan before the war, as opposed to operating from a center of calculation spreading super seeds to parts unseen and distant, such as India (Fujihara 2018, 145–146).

## REFERENCES


Alatas, Syed Hussein. 1977. *The Myth of the Lazy Native: A Study of the Image of the Malays, Filipinos and Javanese from the 16th to the 20th Century and Its Function in the Ideology of Colonial Capitalism*. London: Cass.

Baber, Zaheer. 1998. *The Science of Empire: Scientific Knowledge, Civilization, and Colonial Rule in India*. Oxford: Oxford University Press.

Barnard, Timothy P. 2016. *Nature's Colony: Empire, Nation and Environment in the Singapore Botanic Gardens*. Singapore: NUS Press.

Brockway, Lucile H. 1979. *Science and Colonial Expansion: The Role of the British Royal Botanic Gardens*. Cambridge, MA: Academic Press.

Drayton, Richard. 2000. *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World*. New Haven, CT: Yale University Press.

Fan, Elliott, and Shu-jen Yeh. 2017. "Tenure Security and Long-term Investment on Tenanted Land: Evidence from Colonial Taiwan." *Pacific Economic Review* 24 (4): 570–587. https://doi.org/10.1111/1468-0106.12211.

Fujihara, Tatsushi. 2018. "Colonial Seeds, Imperialist Genes: Horai Rice and Agricultural Development." In *Engineering Asia: Technology, Colonial Development, and the Cold War Order*, edited by Hiromi Mizuno, Aaron S. Moore, and John DiMoia. London: Bloomsbury Academic, Bloomsbury Publishing.

Garner, W. W., and H. A. Allard. 1920. "Effect of the Relative Length of Day and Night and Other Factors of the Environment on Growth and Reproduction in Plants." *Journal of Agricultural Research* 18 (11): 553–606.

Grajdanzev, Andrew J. 1942. *Formosa Today: An Analysis of the Economic Development and Strategic Importance of Japan's Tropical Colony*. New York: Institute of Pacific Relations.

Grove, Richard. 1995. *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600–1860*. Cambridge: Cambridge University Press.

Hayami, Yujiro, Masakatsu Akino, Masahiko Shintani, and Saburo Yamada. 1975. *A Century of Agricultural Growth in Japan: Its Relevance to Asian Development*. Minneapolis: University of Minnesota Press.

Heidegger, Martin. 1993. "The Question Concerning Technology." In *Basic Writings*, edited by David Farrell Krell, 308–341. New York: Harper and Row.

Hirschman, Albert O. 1958. *The Strategy of Economic Development*. New Haven, CT: Yale University Press.

Hung, Kuang-chi. 2015. "When the Green Archipelago Encountered Formosa: The Making of Modern Forestry in Taiwan under Japan's Colonial Rule (1895–1945)." In *Environment and Society in the Japanese Islands: From Prehistory to the Present*, edited by Philip C. Brown and Bruce Batten, 174–193. Corvallis: Oregon State University Press.

Iso, Eikichi. 1947. "Some Considerations on the Regional Adaptability of Rice Varieties with Special Reference to the Recent Development on the Yield per Unit Area in Taiwan." *Bulletin of the Taiwan Agricultural Research Institute* 4: 1–108.

———. 1954. *Rice Crops in Its Rotation in Subtropical Zones*. Tokyo: Japan FAO Association.

Isett, Christopher M. 1995. "Sugar Manufacture and the Agrarian Economy of Nineteenth-Century Taiwan." *Modern China* 21 (2): 233–259.

Ka, Chih-ming. 1995. *Japanese Colonialism in Taiwan: Land Tenure, Development, and Dependency, 1895–1945*. Boulder, CO: Westview Press.

Kim, Tae-Ho. 2018. "Making Miracle Rice: Tongil and Mobilizing a Domestic 'Green Revolution' in South Korea." In *Engineering Asia: Technology, Colonial Development, and the Cold War Order*, edited by Hiromi Mizuno, Aaron S. Moore, and John DiMoia, 189–208. London: Bloomsbury Academic, Bloomsbury Publishing.

Koo, Hui-wen. 2015. "Weather, Harvests, and Taxes: A Chinese Revolt in Colonial Taiwan." *Journal of Interdisciplinary History* 46 (1): 39–59.

Malagayo-Alluri, Fe. 1976. *A Bibliography of Rice Literature Translations Available in the International Rice Research Institute Library and Documentation Center*. Manila: International Rice Research Institute.

Mendiola, Nemesio B. 1949. "Rice in Taiwan." *Philippine Journal of Agriculture* 14 (1): 41–84.

Miyagawa, Takuya. 2008. "The Meteorological Observation System and Colonial Meteorology in Early 20th-Century Korea." *Historia Scientiarum* 18 (2): 140–150.

Olby, Robert. 1987. "William Bateson's Introduction of Mendelism to England: A Reassessment." *British Journal for the History of Science* 20 (4): 399–420.

Pyenson, Lewis. 1989. *Empire of Reason: Exact Sciences in Indonesia, 1840–1940*. Vol. 13 of *Studies in Intellectual History*, edited by A. J. Vanderjagt. Leiden: E. J. Brill.

Quijano, Anibal. 2000. "Coloniality of Power, Eurocentrism and Latin America." *Nepantla: Views from South* 1 (3): 533–580.

Richmond, Marsha L. 2001. "Women in the Early History of Genetics: William Bateson and the Newnham College Mendelians, 1900–1910." *Isis* 92 (1): 55–90.
Schneider, Justin Adam. 1998. "The Business of Empire: The Taiwan Development Corporation and Japanese Imperialism in Taiwan, 1936–1946." PhD diss., Harvard University.
Scott, James C. 1985. *Weapons of the Weak: Everyday Forms of Peasant Resistance*. New Haven, CT: Yale University Press.
———. 1998. *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven, CT: Yale University Press.
Sivasundaram, Sujit. 2013. *Islanded: Britain, Sri Lanka, and the Bounds of an Indian Ocean Colony*. Chicago, IL: University of Chicago Press.
Tilley, Helen. 2011. *Africa as a Living Laboratory: Empire, Development, and the Problem of Scientific Knowledge, 1870–1950*. Chicago, IL: University of Chicago Press.
Tsurumi, E. Patricia. 1977. *Japanese Colonial Education in Taiwan, 1895–1945*. Cambridge, MA: Harvard University Press.
Worboys, Michael. 1979. "Science and British Colonial Imperialism, 1895–1940." PhD diss., University of Sussex.
Wu, Tsong-min. 2001. "Colonization and Growth: The Case of Taiwan." Paper presented at the International Workshop on "Modern Economic Growth and Distribution in Asia, Latin America and European Periphery: A Historical National Accounts Approach," Tokyo, March.
Yao, Jen-to. 2006. "The Japanese Colonial State and Its Form of Knowledge in Taiwan." In *Taiwan under Japanese Colonial Rule, 1895–1945: History, Culture, Memory*, edited by Ping-hui Liao and David Der-wei Wang, 37–61. New York: Columbia University Press.
Zaiki, Masumi. 2007. "Meteorology on the Southern Frontier of Japan's Empire: Ogasawara Kazuo at Taihoku Imperial University." *EASTS* 1 (2): 183–203.