

A Global Green Revolution: Semidwarf Genes from Asia, *Agrónomos*, and the Environmental Laboratory of Mexico, 1953-1970

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Introduction

In 1943, the Mexican government and Rockefeller Foundation (RF) collaborated in the formation of the Mexican Agricultural Program (MAP), which aimed to increase hybrid corn and wheat production. In contrast to the MAP's corn program which failed to convert more than 10 percent of Mexican farmers to hybrid corn, the MAP's wheat program successfully converted over 90 percent of Mexican farmers to rust resistant, semidwarf seeds. This semidwarf seed produced by the MAP's wheat program beginning in 1953 would catalyze the subsequent global Green Revolution in the 1960s. Semidwarf seeds possessed shorter, sturdier stalks that meant farmers could apply massive amounts of inorganic fertilizers to their crops to increase yield without worrying about the stalks bending over and breaking. Between 1953 and 1970, semidwarf wheat allowed Mexican farmers to increase wheat production 220% and yield 150%. As a result of this success, the MAP's wheat program became the model for the subsequent Green Revolution in the 1960s: the global spread of industrialized agriculture predicated on semidwarf crops and inorganic fertilizer use.¹

As recent work by Gabriela Soto Laveaga argues, Mexico, in particular, Sonora, became the birthplace of the Green Revolution.² Following the development of semidwarf wheat in Mexico, MAP scientists facilitated their growth next in India and

Received June 12, 2022; Reviewed August 19, 2022; Accepted August 19, 2022.

DOI: <http://dx.doi.org/10.36092/KJHS.2022.44.2.339>

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¹ Data on Mexican wheat production derive from Stephen Lewontin's oft-cited dissertation in the historiography of the Green Revolution. Lewontin's corn and wheat data for 1925 to 1965 are official statistics from the Dirección General de Economía Agrícola's "Centro de Investigaciones Agrarias" pages 152-153 (corn) and pages 156-157 (wheat). Lewontin's corn and wheat data for 1965 to 1970 are official statistics from the Dirección General de Economía Agrícola's *Anuario Estadístico*, 1968-1973. Stephen Lewontin, "The Green Revolution and the Politics of Agricultural Development in Mexico Since 1940," Doctoral Dissertation, University of Chicago, 1983.

² Gabriela Soto Laveaga, "Beyond Borlaug's Shadow: Octavio Paz, Indian Farmers, and the Challenge of Narrating the Green Revolution," *Agricultural History* 95 (2021), 580.

Pakistan in the 1960s, and by the early 1970s farmers throughout Asia and North Africa devoted large shares of their wheat acreage to high-yielding semidwarf wheats: India (52%), Nepal (66%), Pakistan (56%), Lebanon (31%), Algeria (28%).³ The MAP's wheat program is critical to understanding modern rice production in Asia as well because the MAP served as the model for the creation of the International Rice Research Institute in the Philippines which created and disseminated high-yielding semidwarf rice throughout Asia.⁴ For example, South Korean farmers grew semidwarf rice, modeled after the MAP's wheat program, on around 16 percent of land devoted to rice production in the 1972-1973 growing season while South Asia and Southeast Asia devoted large shares of their rice acreage to new high-yielding semidwarfs: Pakistan (43%), India (25%), Philippines (56%), Indonesia (18%), Malaysia (38%), Vietnam (32%).⁵ In the early 1970s, farmers grew high-yielding, semidwarf wheat on nearly 42 million acres of land and high-yielding semidwarf rice on nearly 39 million acres of land in Asia and North Africa alone.⁶

John Perkins argues increased food production during the Green Revolution assuaged neo-Malthusian concerns about overpopulation during the Cold War which emanated from national security experts, especially in the U.S.⁷ Farmers in the Global South increased the production of staple crops, namely wheat and rice, 200 percent to 300 percent or more, and this enabled global population to surge from 3 billion in 1960 to nearly 8 billion today.⁸ The Green Revolution, however, was not

³ Dana G. Dalrymple, "Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations," *USDA, Foreign Agricultural Economic Report* 95, 1978, 72.

⁴ The presidents of the RF and Ford Foundation (FF), J.G. Harrar and F.F. "Frosty" Hill, took the same train to work in New York City, and they formulated the plan to create the International Rice Research Institute on their commute and subsequent joint meetings between the two foundations. Hill remarked to Harrar during one meeting, "you know George [Harrar], someone should undertake to work with rice the way you Rockefeller Foundation people have with corn and wheat," in the MAP. The FF would pay for the cost of the IRRI, and it would entrust staffing and running the program to the RF. The RF staff based their work on semidwarf rice in Asia on the MAP's work on wheat. Many of the early leaders of the IRRI had worked at the MAP, and they used this experience to create a parallel program on semidwarf rice in the Philippines. Helen Anne Curry, "From working collections to the World Germplasm Project: agricultural modernization and genetic conservation at the Rockefeller Foundation," *History of Philosophy of the Life* 39 (2017), doi: 10.1007/s40656-017-0131-8; Robert F. Chandler, Jr., *An Adventure in Applied Science: A History of the International Rice Research Institute* (Manila, Philippines: International Rice Research Institute Press, 1992), 1-5; Robert S. Anderson, "The Origins of the International Rice Research Institute," *Minerva* 29 (1991), 64, 75-80, 85.

⁵ Rice figures exclude Japan and Taiwan. It is still unclear the impact the seeds of the Green Revolution had on China. *Ibid*, 50, 67, 72.

⁶ *Ibid*.

⁷ John H. Perkins, *Geopolitics and the Green Revolution: Wheat, Genes, and the Cold War* (New York: Oxford University Press, 1997), 102-120.

⁸ "Population, total," *The World Bank Data*, accessed January 1, 2022, <https://data.worldbank.org/indicator/SP.POP.TOTL>.

a rising tide that lifted all boats. Green Revolution policies and programs privileged subsidies and agricultural research that benefitted largescale, affluent farmers which increased rural inequality in the Global South.⁹ On the consumer side, the Green Revolution aimed to feed burgeoning urban populations and largely bypassed the rural poor, contributing to out-migration from the countryside: in 1960, two-thirds of the world's population lived in rural areas, but by 2007, the majority of the world population lived in urban areas and were divorced from agricultural production.¹⁰

Early scholars of the Green Revolution emphasized the role of U.S. scientists working for the RF for the scientific work that gave rise to the Green Revolution. Fitzgerald argues the MAP was an example of the U.S. "exporting" its model of agricultural production to Mexico, while Nick Cullather describes how the Green Revolution was heavily influenced by domestic developmental work in the U.S. South such as the Tennessee Valley Authority.¹¹ More recently, scholars of the Green Revolution have begun to explore the role of Mexican actors in the creation of the Green Revolution, but these narratives have focused predominantly on corn. Karin Matchett was one of the first to focus on Mexican actors and argues the Mexican government forced the RF to abandon research on synthetic corn she believes would have benefitted the rural poor to focus on hybrid corn grown by affluent farmers. Jonathan Harwood concurs and describes the "peasant-friendly" corn breeding during the early years of the MAP, while Tore Olsson focuses on corn to explain the parallel nature and connections of U.S. and Mexican agrarian campaigns in the decades preceding the MAP.¹²

⁹ In 1995, Donald K. Freebairn reviewed over 300 studies on the Green Revolution. He found that the majority of scholarship found the Green Revolution caused inequality to increase, "both inter-farm and interregional. This evidence diverges from the position of action agencies which support and participate in this technological strategy toward agricultural and rural development." Donald K. Freebairn, "Did the Green Revolution Concentrate Incomes? A Quantitative Study of Research Reports," *World Development* 23:2 (1995), 265.

¹⁰ The Green Revolution improved production on largescale farms that chipped away at the profitability of small-scale, peasant farming. Many peasants and landless laborers had to exit the countryside to find work. While in the early years of the Green Revolution, labor demand in the countryside increased, largescale farmers quickly mechanized which eliminated much of this demand for rural labor. "World Development Indicators," *The World Bank*, accessed November 11, 2020, <https://datacatalog.worldbank.org/dataset/world-development-indicators>.

¹¹ Deborah Fitzgerald, "Exporting American Agriculture: The Rockefeller Foundation in Mexico, 1943-1953," *Social Studies of Science* 16:3 (1986), 457-462; Nick Cullather, *The Hungry World: America's Cold War Battle against Poverty in Asia* (Cambridge: Harvard University Press, 2010).

¹² Karin Matchett, "At Odds over Inbreeding: An Abandoned Attempt at Mexico/United States Collaboration to 'Improve' Mexican Corn, 1940-1950," *Journal of the History of Biology* 39 (2006), 345-352, 366-369; Jonathan Harwood, "Peasant Friendly Plant Breeding and the Early Years of the Green Revolution in Mexico," *Agricultural History* 83:3 (2009), 385-387, 396-401; Ultimately, Olsson's work focuses more on the U.S. as it seeks to "emancipate" the U.S. South from the "straitjacket of national history." Tore Olsson, *Agrarian Crossings: Reformers and the*

While this recent scholarship on corn challenges the U.S.- and RF-centered historiography of the Green Revolution, the MAP's failed corn program did not inspire the Green Revolution. This article focuses exclusively on wheat which became the centerpiece of the Green Revolution, and it deepens the recent work by Laveaga that emphasizes the Mexican origins of the Green Revolution. This article introduces the role of the Mexican environment in the creation of the Green Revolution and argues MAP scientists were so successful in breeding new wheat varieties because they treated Mexico as an "environmental laboratory." MAP scientists invented a new breeding strategy called shuttle breeding to leverage Mexico's environmental diversity, and this article finds the key ideas and push behind this innovation derived from Mexican agricultural scientists, known as *agrónomos* in Mexico. Finally, this article complicates Laveaga's view that Mexico was the birthplace of the Green Revolution: semidwarf genes that made the seeds of the Green Revolution so appealing to farmers and scientists derived from Asia, and this region has been downplayed in the historiography of the Green Revolution.

Formative Years of the MAP (1943-1953)

In 1943, the Mexican government invited the RF into Mexico to assist with improving agricultural production in what was known as the Mexican Agricultural Program (MAP). The Mexican government sought to support largescale farmers that provisioned the burgeoning urban classes that underpinned Mexico's industrial turn. Wheat bread consumption in the nineteenth and twentieth centuries was beyond the means of the rural poor in Mexico, also known as *campesinos*, so Mexican farmers that grew wheat catered to urban consumers with purchasing power. Historically, middle- and upper-class consumers demanded wheat bread as a sign of both economic and racial superiority, but by the twentieth century wheat consumption came to define an urban-rural divide. In 1950, only a little over half the Mexican population consumed bread, primarily those that drove urban-industrialization: 95 percent of Mexico City's residents consumed wheat, while less than 30 percent of consumers in predominantly rural states ate bread consistently.¹³

The RF hired three plant pathologists from the University of Minnesota (UMN), E.C. Stakman, J.G. Harrar, and Norman E. Borlaug, to conduct research on wheat.

Remaking of the U.S. and Mexican Countryside (Princeton: Princeton University Press, 2017), 1-5, 150-155.

¹³ For example, rural states like Tlaxcala, Guanajuato, Querétaro, and Zacatecas reported under 30 percent wheat consumption "Séptimo Censo General de Población 1950," *Instituto Nacional de Estadística y Geografía*, C22, Distribución porcentual de la población de 1 año y más, por entidad federativa y sexo, según características de alimentación y calzado, 1953, accessed November 11, 2020, <https://en.www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825412432>.

The MAP also leveraged the expertise of *agrónomos* such as Ricardo Manso Leon, Edmundo Taboada, and Ignacio Narvaez, all with expertise in plant pathology, for wheat research. Under the umbrella of the MAP, these Mexican and U.S. scientists concentrated first on breeding novel wheat seeds with resistance to plant disease called wheat rust, a fungus which was a major impediment to the growth of wheat in both the U.S. hard red spring wheat region (Minnesota, North Dakota, South Dakota) and northern Mexico, in particular the state of Sonora. Courtney Fullilove's recent work reveals that agricultural knowledge and labor impeded the commercial growth of wheat in the central Midwest, and the United States Department of Agriculture's M.A. Carleton addressed this by encouraging German Mennonite immigration to create the hard red winter wheat region (Kansas and Nebraska).¹⁴ Further north in the hard red spring wheat region, plant disease, not labor or agricultural knowledge, impeded the commercial growth of wheat farming. As my forthcoming article in *Agricultural History* reveals, wheat rust mitigation was central to the growth of the hard red spring wheat region, and UMN scientists like Stakman, who later became a prominent advisor to the RF's work in Mexico, would argue that wheat rust was a transnational problem that required international collaboration to reduce the harm in both Minnesota and Mexico.¹⁵ In the first decade of the MAP when scientists focused on rust research, over 80 percent of Mexican farmers converted to seeds disseminated by the MAP: farmers were able to boost Mexican wheat production 84 percent and yields 59 percent by 1953, but they hit a biological ceiling on yield growth that required further innovation.¹⁶

¹⁴ Courtney Fullilove, *The Profit of the Earth: The Global Seeds of American Agriculture* (Chicago: University of Chicago Press, 2017), 100-138.

¹⁵ See forthcoming article John R. Garnett, "Winds of Change Plant Pathology, Transnational Wheat Rust, and the Environmental Origins of the Green Revolution, 1904-1953," *Agricultural History* 97:2 (May 2023).

¹⁶ Lewontin, "The Green Revolution and the Politics of Agricultural Development in Mexico," 156-157.

Korean Origins of Semidwarf Genes (1500-1870)

Beginning in 1953, the MAP focused on breeding semidwarf wheat that enabled farmers to utilize massive amounts of inorganic fertilizer to produce more grain. Natural gas-based fertilizer, a byproduct of oil production, became the lifeblood of the Green Revolution, which swept through nations in the Global South as they sought to follow Mexico's example and produce more food to fuel urban industrialization. As Borlaug described it, semidwarfs were the "catalysts that have ignited the green revolution" while "chemical fertilizer is the fuel that has powered its forward thrust."¹⁷

Why were semidwarfs so critical for the globalization of industrialized agriculture predicated on inorganic fertilizer use? Before 1953, farmers hit a biological ceiling that limited the amount of wheat they could produce using fertilizer. Conventional wheat had long stalks which could not sustain the excess grain at the top that heavy fertilization produced. Heavily fertilized wheat was prone to bending over, or "lodging," which meant farmers could not harvest it using machine technology. Oftentimes, lodged wheat collapsed to the ground, and this caused the grain head to "shatter." All the wheat kernels would fall off the plant and onto the ground leaving nothing at all to harvest. The MAP anticipated this problem with lodging as it saw the demand for fertilizer increase, and it preemptively began breeding semidwarf wheat that had shorter, sturdier stalks in 1953. This improvement in the wheat plant's architecture supported the increase in grain that massive amounts of fertilizer application made possible, and without this dwarfing gene the Green Revolution would never have come to fruition.

Given the importance of this dwarfing gene to the spread of the Green Revolution, it is important to identify its origins. Semidwarf wheat was not indigenous to Europe or the U.S. It was first developed by farmers and scientists in Korea and Japan between 1500 and 1900, and U.S. and Mexican scientists only began their own work on this Asian biotechnology in the mid-1950s. Korean farmers selected and grew semidwarf wheat varieties between the third and fourth centuries C.E.¹⁸ They named it Jinju native wheat or Anzunbaengmil wheat in the southern part of the Korean peninsula, and they commonly described it as "cripple wheat" because of its unique dwarf stature (height between 50 and 80 cm).¹⁹ Anzunbaengmil's gluten content

¹⁷ Norman Borlaug, "Norman Borlaug Nobel Lecture: The Green Revolution, Peace, and Humanity," *The Nobel Prize*, December 11, 1970, accessed August 3, 2020, <https://www.nobelprize.org/prizes/peace/1970/borlaug/lecture/>.

¹⁸ C.H. Cho et al., "Origin, dissemination and utilization of semi dwarf genes in Korea," in *International Proceedings of the 7th International Wheat Genetic Symposium*, eds. T.E. Miller and R.M.D. Koebnereds (Bath: Bath Press), 223–231.

¹⁹ U.S. scientists often spelled this wheat Anjeunbaengi. "The Rockefeller Foundation Program in Agriculture: William C. Cobb Interview of Norman E. Borlaug," *Rockefeller Foundation*, June 12, 1967, 83, International Maize Wheat Improvement Center Collection, Norman E. Borlaug

was too low to produce high-quality bread as consumed in Europe: it was closer to the quality of soft wheats, and produced a slightly reddish flour.²⁰ Anzunbaengimil was used in traditional foods including “a custom called Millsari, in which children would burn wheat berries, rub them between their hands and eat them as an alternative during poor times,” and it was a key ingredient in “sujebi (clear soup with dumplings), kalguksu (handmade noodles), and buchimgae (Korean style pancakes).”²¹

The Creation of Norin 10: Global Technology Transfer from Japan (1870-1953)

C.H. Cho et al. argue these Korean semidwarf wheats were introduced to Japan after the failed sixteenth century invasion of the Korean Peninsula by the Japanese, known as the Imjin Wars.²² Evidence points to Korean semidwarf wheats being experimented with by Japanese scientists at the latest in the 1870s.²³ In 1873, Horace Capron, former U.S. Commissioner of Agriculture, headed an agricultural advisory mission to Japan where he observed that “the Japanese farmers have brought the art of dwarfing to perfection...on the richest soils and with the heaviest yields, the wheat stalks never fall down and lodge.”²⁴ In Japan, farmers and scientists renamed Anzunbaengimil, Daruma, after Bodhidharma, the Buddhist monk that was a leader in establishing the Zen branch of East Asian Buddhism.²⁵ The oft-repeated popular legend of Bodhidharma claims he was denied entry to a Shaolin temple at Mount Song, so he sat meditating in a nearby cave for nine years without standing up once. Daruma came to mean “no legs” and “do not tumble down” in Japanese, which would explain why dwarf wheat received this name.²⁶ Unlike conventional wheat that is

Digital Archive, College of Agriculture & Life Sciences, Texas A&M University, College Station, Texas (TAMU).

²⁰ Chul Soo Park et al., “Evaluation of Cookie Quality from Semi-dwarf Korean Landrace Crippled Wheat ‘Anzunbaengimil,’” *Journal of Agriculture & Life Science* 47:5 (2013), 257.

²¹ “Anjeunbaengi Wheat,” *Slow Food Foundation for Biodiversity*, accessed January 27, 2022, <https://www.fondazione Slow Food.com/en/ark-of-taste-slow-food/anjeunbaengi-wheat/>.

²² After the failed invasions, the Japanese kept a settlement in Busan and more research is needed to unearth the process and timing of when this wheat reached Japan. C.H. Cho et al., “Origin, dissemination and utilization of semi dwarf genes in Korea,” 223–231.

²³ “William C. Cobb Interview of Norman E. Borlaug,” 83.

²⁴ Dana G. Dalrymple, “Development and Spread of Semidwarf Varieties of Wheat and Rice in the United States: An International Perspective,” *United States Department of Agriculture, Agricultural Economic Report* 455 (1980), 2.

²⁵ “William C. Cobb Interview of Norman E. Borlaug,” 83.

²⁶ Kihara, H., “Origin and history of ‘Daruma,’ a parental variety of Norin 10” in S. Sakamoto, ed. *Proc. 6th Int. Wheat Genetics Symp.* (Plant Germplasm Institute, University of Kyoto, Kyoto, Japan & Beijing, China Agricultural Sciencetech Press, 1983).

prone to bending over or falling down and breaking when the grain at the top becomes too heavy, semidwarf wheat's short stature made it resistant to lodging without a decline in yield. Daruma dolls became popular in Japan as a gift that brings luck and prosperity, and Japanese scientists gave semidwarfs this name to communicate the fortuitous discovery of these unique semidwarfs.²⁷

At the turn of the twentieth century, scientific breeding programs were key to boosting agricultural production as Japan industrialized and militarized. In 1900, Japan's population of 44 million lived on 93 million acres of land compared to the U.S. in which 76 million people lived on 2.43 billion acres of land. U.S. farmers were able to increase agricultural production through extensive practices, while Japanese farmers focused on intensive practices due to land constraints. Japan had 94 percent less land per capita, so Japanese scientists were intrigued by the potential of Norin 10 as a land-saving agricultural technology.²⁸ Increased agricultural production was critical for sustaining population increases as well: at the beginning of the Meiji Reforms in 1868, the Japanese population stood at 34 million, but by 1900 the population had increased by around 29 percent.²⁹ By 1930, the population had increased another 45 percent, and it hovered around 70 million throughout the 1930s. Japanese scientists were also interested in developing shorter crops due to environmental reasons. Harrar, the first leader of the MAP and later President of the Rockefeller Foundation during the Green Revolution, described how the Japanese were "wise in developing shorter and sturdier varieties. In the monsoon belt where sunlight may be short during the growing season, the shorter plants do not shade themselves and each other as much as the tall ones do."³⁰ With more limited exposure to sunlight, Japanese scientists sought to develop dwarf staple crops, including rice and wheat, that would not block neighboring plants' access to sunlight.

Japanese scientists used Daruma to breed a variety of semidwarf wheat they named Norin 10 in the early twentieth century, and it would be this variety that Mexican and U.S. scientists used to create the semidwarf seeds that gave rise to the Green Revolution. As an official at the United States Department of Agriculture (USDA) describes it, "virtually all of the semi-dwarf varieties grown in the less developed countries utilize the dwarfing genes (Rht1 and Rht 2) contained in two Japanese varieties... Daruma is by far the most important source, principally through the use

²⁷ "William C. Cobb Interview of Norman E. Borlaug," 83.

²⁸ Borlaug, "Japan's Contributions to the Development of the Green Revolution," 345-346.

²⁹ "Population, 1800 to 2100," *Our World in Data*, accessed January 10, 2022, <https://our-worldindata.org/grapher/projected-population-by-country?country=~JPN>.

³⁰ J. George Harrar, "Blueprint for Hungry Nations: The Mexican Agricultural Program of the Rockefeller Foundation," 1961, Harrar History, 7-8, J. George Harrar Papers, Record Group IV2A26, Box 41, Folder 301, Rockefeller Foundation (RF), Rockefeller Archive Center (RAC), Tarrytown, New York.

of its best-known offspring, Norin 10.”³¹ While Japanese scientists used Daruma to transfer the genes that carried dwarf characteristics into Norin 10, they utilized a U.S. wheat to increase quality. In 1892, Japanese scientists acquired Glassy Fultz from the U.S. for testing which had excellent environmental adaptability as well as high-quality, high-gluten characteristics.³² In 1862, Abraham Fultz selected a wheat seed from a field in Lancaster, Pennsylvania which “became a well-marked and popular variety, called Fultz from the name of the breeder,” and at the turn of the twentieth century it was one of the “best known of American wheats.”³³ M.A. Carleton of the USDA described how the agency promoted Fultz’s growth in the 1870s for its flexibility in flour production. He found “it comes nearest to being a general purpose wheat” of all U.S. varieties, and it was “rather early ripening, fairly hardy, and possesses a semi-hard, red kernel of good quality.”³⁴ The adjective “glassy” was added to wheats at the turn of the twentieth century to communicate high gluten quality because “when the ratio of gluten to starch is sufficiently high” a wheat “takes on a hard, glassy, semitranslucent texture.”³⁵

Scientists at the Central Agricultural Experiment Station at Nishigahara in Tokyo first tested introductions of Fultz and identified a high-protein variety, Glassy Fultz, which they utilized as a good all purpose, high-quality wheat for breeding.³⁶ In 1917, Japanese scientists successfully achieved a viable cross between Glassy Fultz (male parent) and Daruma (female parent) to produce Fultz-Daruma.³⁷ Japanese scientists purified Fultz Daruma for six generations until 1923, a process called pedigree selection, before using it to crossbreed with other wheat varieties.³⁸ They next crossed

³¹ Dalrymple describes how “Daruma is an ancestor of two well-known Korean semi-dwarf varieties, Suwon 92 and Seu Suen 27” which were used to breed semidwarfs during the Green Revolution as well as for planting in the U.S. Dalrymple, “Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations,” 22.

³² Gonjiro Inazuka, “II. Genetic Stock: *Norin 10*, a Japanese semi-dwarf wheat variety,” in *Wheat Information Service of Yoshida College, Kyoto University* Number 32 (1970), 25. Accessed December 1, 2021, <http://shigen.nig.ac.jp/shigen/index.jsp>. Dalrymple finds Japan imported this in 1887; Dalrymple, “Development and Spread of Semidwarf Wheat and Rice in the United States,” 31-32.

³³ Mark A. Carleton, *The Small Grains* (New York: MacMillan Company, 1920), 199-200.

³⁴ Ibid.

³⁵ The USDA described how “in the absence of a sufficient proportion of gluten to hold the cell contents together, the shrinkage in drying does not fully compensate for the loss of water, and air spaces appear within the cells. These open spaces render the grain soft and, also, since they serve as refracting surfaces, make it opaque. We are, therefore, accustomed to associate softness, opaqueness, and low gluten content in wheats.” J. Allen Clark, John H. Martin, and Carleton R. Ball, “Classification of American Wheat Varieties, 1923,” *United States Department of Agriculture, Bulletin* 1074 (1923), 42.

³⁶ L.P. Reitz and S.C. Salmon, “Origin, History, and Use of Norin 10 Wheat,” *Crop Science* 8:6 (1968), 687.

³⁷ Inazuka, “II. Genetic Stock: *Norin 10*,” 25.

³⁸ Ibid.

Fultz-Daruma (male parent) with Turkey Red (female parent), a Crimean wheat brought to the U.S. by German Mennonites in the late-nineteenth century, at the Ehime Agricultural Experiment Station in 1926.³⁹ Gonjiro Inazuka, born into a poor peasant farming family in 1897, graduated from the National Agricultural College, and he became one of the lead scientists that worked on Norin 10. He described how Norin 10 was the result of Japanese scientists setting up “systematic” wheat breeding programs in the 1920s, and the goal in the creation of Turkey Red x Fultz-Daruma was to breed a semidwarf wheat with short stature and disease resistance.⁴⁰

Further testing was done at the Konosu Bran Station by Morimasa Yamazaki and Sunsumu Hatano, and between 1927 and 1930, Inazuka received thirty wheat varieties at Iwate Agricultural Experiment Station at Morioka, where he spent twenty years directing efforts to make Norin commercially viable.⁴¹ In 1935, Inazuka formally released Norin 10, and in Yamagata Prefecture Japanese farmers adopted it for commercial planting on about a quarter of their land between 1942 and 1951.⁴² While Norin 10 reached the hands of MAP scientists in the 1950s, this was not the only semidwarf wheat from Asia that scientists utilized in breeding programs. Italian breeders acquired a Japanese wheat named Akakomugi for its dwarf characteristic, and scientists are unsure if Daruma and Akakomugi share a common ancestor. It is possible Akakomugi may have followed a similar journey from Korea to Japan before Nazareno Strampelli used it as part of a national wheat breeding program supported by Mussolini’s fascist government.⁴³ Strampelli used Akakomugi as a parent in the creation of Mentana which was used by scientists in both Mexico and Brazil before it became a part of the MAP’s wheat breeding program.⁴⁴

While European scientists like Strampelli were already incorporating Asian semidwarfs into breeding programs in the early twentieth century, it was only during the

³⁹ “Development and Spread of Semidwarf Wheat and Rice in the United States,” 31-32.

⁴⁰ Inazuka, “II. Genetic Stock: *Norin 10*,” 25-26.

⁴¹ Norman E. Borlaug, “The Green Revolution: Its Origin and Contributions to World Agriculture,” *Journal of Bioresource Sciences* 4:1 (2003), 13; “Description of Japanese variety Norin no.1,” Undated, Norman E. Borlaug Digital Archive, College of Agriculture & Life Sciences, TAMU; Norman Borlaug, “Japan’s Contributions to the Development of the Green Revolution Semidwarf Wheat Varieties,” in *Norman Borlaug on World Hunger* ed. Anwar Dil (San Diego: Bookservice International, 1997), 345-346.

⁴² Inazuka, “II. Genetic Stock: *Norin 10*,” 29.

⁴³ Italy had an extensive wheat breeding program led by Nazareno Strampelli that was “obsessed” with improving yield. Tiago Saraiva discusses how “The Battle of Wheat” in Italy reduced agricultural diversity and harmed the environment in order to produce more wheat for Mussolini’s nationalist agenda. Saraiva discusses how geneticists played a “major role in the process of building the New State.” Tiago Saraiva, *Fascist Pigs: Technoscientific Organisms and the History of Fascism* (Cambridge: The MIT Press, 2016), 22-42.

⁴⁴ S. Salvi, O. Porfiri, and S. Ceccarelli, “Nazareno Strampelli, the ‘Prophet’ of the green revolution,” *The Journal of Agricultural Science* 151:1 (2013), 1-3; Alain P. Bonjean, William J. Angus, and Maarten van Ginkel, ed., *The World Wheat Book: A History of Wheat Breeding* (Paris: Lavoisier Publishing, 2001), 289-309.

occupation following World War II that U.S. scientists grasped the potential of semidwarf wheat from Asia. In 1946, General Douglas MacArthur, in charge of the U.S. postwar occupation, requested U.S. scientists help improve agricultural production in war-torn Japan. In response, the USDA sent S.C. Salmon to Japan, and he saw semidwarf wheat growing at Morioka Branch Station.⁴⁵ Salmon sent Norin 10 and fifteen other types of semidwarf wheat back to the USDA for testing in Beltsville, Maryland.⁴⁶ The USDA and Washington State University jointly tested these semidwarf wheats, and Orville Vogel identified Norin 10 as the most promising semidwarf for breeding programs. Vogel crossbred Norin 10 with a wheat called Brevor whose ancestors derived from the Crimea, Ukraine, Australia, Italy, the U.S. and India. MAP scientists used Norin 10-Brevor extensively in breeding semidwarf wheats for Mexico and the Green Revolution, but no one nation, individual, or institution can be credited with these foundational seeds of the Green Revolution. Key improvements in quality and environmental adaptability derived from Australia, Europe, and the U.S. while the most important characteristic, semidwarf stature, derived from Korea and Japan.

La Revolución Verde: *Agrónomos*, Shuttle Breeding, and the Environmental Laboratory of Mexico

While Asian farmers and scientists selected and bred semidwarf characteristics into wheat, Mexican actors were central to integrating these Asian semidwarfs into the seeds that would give birth to the Green Revolution. Vogel sent promising crosses of Norin 10-Brevor to Borlaug, the leader of the MAP's wheat program at the time, for testing in the environmental laboratory of Mexico in 1953.⁴⁷ Borlaug led the MAP's wheat program during the early years of semidwarf wheat development, but he did not work alone. Hundreds of Mexicans, including *agrónomos* and blue-collar agricultural workers and wheat technicians, conducted the majority of crosses, selections, and testing over the course of seven years to produce semidwarf wheat.

Before gene mapping in the 1950s, scientists relied upon largescale breeding programs to simply test thousands of different wheat varieties and crosses. This was difficult technical work that involved thousands of hours as scientists and agricultural technicians crossbred wheat. The MAP's wheat breeding program was unique due to Mexico's environmental diversity. As a nation Mexico is ranked fourth or

⁴⁵ Louis P. Reitz, "Short Wheats Stand Tall," in *The Yearbook of Agriculture 1968* (Washington D.C.: Government Printing Office, 1968), 236-240.

⁴⁶ Ibid.

⁴⁷ Norin 10-Brevor was released in the Pacific Northwest as Gaines, and farmers achieved some of the highest yields on record in the 1960s using massive amounts of fertilizer with Gaines. Ibid.; Bayles, "Classification of Wheat Varieties Grown in the United States in 1949," 52.

fifth globally in environmental and species diversity and is considered a “mega-diverse” nation.⁴⁸ Spanning around 1.2 million square miles, Mexico is only 1.31 percent of all land globally, but its environment is so diverse that it contains around 10 percent of “worldwide biotic diversity” with 50 percent of Mexico’s species being endemic.⁴⁹ The MAP leveraged this environmental diversity to test and breed wheat seeds throughout all of Mexico. Wide testing led to the discovery of unique characteristics in different wheat types, but more importantly, it served as a survival of the fittest test. Only the best wheats could survive the gamut of environmental conditions in Mexico, and a wheat that could grow widely in Mexico could also grow in most other world regions. Mexico was like a condensed version of the world from an environmental perspective and became an environmental laboratory for producing universal wheat seeds that had the potential to grow globally.

The use of Mexico as an environmental laboratory coincided with the rise of laboratory science in the twentieth century in which scientists touted laboratories as sites of knowledge production.⁵⁰ This “revolution” in laboratory science resulted from scientists who privileged experimentation and practice over theoretical science, and at the turn of the twentieth century, many U.S. and European scientists even saw colonies or imperial possessions as ideal spots for experimentation.⁵¹ Hellen Tilley argues that the British government treated its African colonies as a “living laboratory” in which to test out different social policies and other government programs on Africa’s human population in the late nineteenth- to the mid-twentieth century. Mexican technocrats and the RF looked to turn the environment into a laboratory and conduct a massive number of tests and crosses across as many different regions as possible. As such, the MAP’s early research emphasized basic research on wheat

⁴⁸ Gian Carlo Delgado, “Biopiracy and Intellectual Property as the Basis for Biotechnological Development: The Case of Mexico,” *International Journal of Politics, Culture, and Society* 16:2 (2002), 307; Isolda Luna-Vega et al., “Geographical patterns and determinants of species richness in Mexico across selected families of vascular plants: implications for conservation,” *Systematics and Biodiversity* 11:2 (2013), 237-238.

⁴⁹ Delgado finds 8 to 12 percent of species in the world are found in Mexico. Luna-Vega et al. find 10 percent of global biodiversity is located within Mexico. Ibid. Statistics on land are derived from “The World Factbook,” *Central Intelligence Agency*, accessed April 5, 2019, <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2147rank.html>.

⁵⁰ Robert Fox and Anna Guagnini, *Laboratories, Workshops & Sites: Concepts & Practices of Research in Industrial Europe, 1800-1914* (Berkeley: University of California Press, 1999); Frank A.J.L. James, ed., *The Development of the Laboratory: Essays on the Place of Experiments in Industrial Civilization* (London: Palgrave Macmillan, 1989); Andrew Cunningham and Perry Williams, ed., *The Laboratory Revolution in Medicine* (Cambridge: Cambridge University Press, 1992).

⁵¹ Roy MacLeod, ed., *Nature and Empire: Science and the Colonial Enterprise* (Chicago: University of Chicago Press, 2000); Patrick Carroll, *Science, Culture, and Modern State Formation* (Berkeley: University of California Press, 2006); Eugene Cittadino, *Nature as the Laboratory: Darwinian Plant Ecology in the German Empire, 1880-1900* (New York: Cambridge University Press, 1990).

rust in the diverse environmental conditions of Mexico before shifting to semidwarfs in 1953. The Mexican government was complicit in this use of Mexico as an environmental laboratory, and *agrónomos* actually pushed wide experimentation throughout Mexico as long as it improved agricultural production.

In the early years of the MAP, scientists tested wheat primarily in Chapingo, in south-central Mexico adjacent to Mexico City. The Mexican government wanted the MAP to facilitate the creation of a new industrial bread basket in northwestern Mexico, and the *agrónomo* Ricardo Manso León pushed Borlaug to bring all the wheat seed that the MAP was working on in Chapingo to Sonora in the Northwest. This marked the first example of “shuttle breeding” or the growth of two generations of wheat in different environmental regions in one calendar year.⁵² Manso had received a fellowship to learn about soil conservation in the U.S., and upon his return to Mexico he took over as the director of the Sonoran experiment station.⁵³ He had “no experience in experimentation in agronomy or plant breeding” but he was eager to learn and to use the MAP to bolster his work in the Northwest.⁵⁴ Manso’s work suffered from underfunding, and he asked the MAP to help by bringing its breeding material to Sonora. Manso and other *agrónomos* adopted a strategy of experimenting widely in Mexico, even if some of these practices were viewed as scientifically unsound by U.S. scientists. In 1945, Borlaug had only been to Sonora once and had done no planting there, but “in the fall of [19]45 Leon Manso told the MAP, ‘you send Borlaug up to [Sonora] and bring all the material [seeds] you can.’”⁵⁵ Manso had access to the *agrónomo* Edmundo Taboada’s wheat seed collection, and he directed Borlaug to help organize and plant both sets of seeds at the Sonoran experiment station. The next year Borlaug returned, again growing wheat from central Mexico in Sonora, and the first example of shuttle breeding occurred in 1946 following Manso’s demand.⁵⁶

By the late 1940s, *agrónomos* and RF scientists made shuttle breeding a core practice at the MAP. Each shuttle breeding season started by planting wheat in the winter during “the commercial wheat crop season” in the northwestern state of Sonora.⁵⁷ This exposed wheat to low-elevation, semiarid environmental conditions, and the

⁵² Norman E. Borlaug, “N.E.B.’s Autobiography OEE Part 1,” 1990, 34, International Maize Wheat Improvement Center Collection, Norman E. Borlaug Digital Archive, TAMU.

⁵³ Ibid.

⁵⁴ Ibid.

⁵⁵ Ibid., 40.

⁵⁶ There is also an isolated reference that shuttle breeding may have been a Mexican politician’s idea. Brian D. Wright describes how David Zilberman told him that “Borlaug told him that a Mexican bureaucrat suggested the idea of shuttle breeding.” Brian D. Wright, “Grand missions of agricultural innovation,” *Research Policy* 41 (2012), 1721; Borlaug, “N.E.B.’s Autobiography OEE Part 1,” 40–42.

⁵⁷ Norman E. Borlaug, “Wheat Breeding and its Impact on World Food Supply,” *Third International Wheat Genetics Symposium*, 1968, 5, Elvin C. Stakman papers, Box 3, Folder 20, University Archives, University of Minnesota, Twin Cities (UMN).

MAP isolated wheats that possessed rust resistance or unique characteristics that warranted further testing. MAP scientists then drove the wheat seeds over 1,300 miles south where “a second generation was obtained by planting during mid-May at 8,500 feet at 18 degrees latitude near Toluca.”⁵⁸ MAP scientists grew this second generation in the region known as the Bajío, the traditional breadbasket of Mexico located adjacent to Mexico City, and it exposed the wheats to high-elevation growing conditions. This was also a highly conducive environment for the proliferation of plant diseases, especially fungi, because of the cool, wet climate of the spring planting season.⁵⁹ Farmers in the Bajío not only contended with wheat stem rust, but leaf rust and stripe rust also chipped away at yields.

Shuttle breeding was critical to the success of the MAP’s wheat program for three reasons: MAP scientists were able to generate new crosses in half the time of other conventional breeding programs in the U.S., the wide testing in the environmental laboratory of Mexico revealed unique characteristics of wheat, and wheat that grew anywhere in Mexico could be adapted easily to grow throughout much of the world. Conventional wheat breeding programs in the U.S. took “the plant breeder and plant pathologist about ten years” to release a new seed technology; at best an accelerated wheat breeding program might release a new seed in six to seven years.⁶⁰ The U.S. scientific consensus at the time held that breeding two generations of wheat in one year would produce crosses that would fail to grow.⁶¹ U.S. scientists believed that they could produce only one generation of wheat per year, and any seed produced by growing more than one generation a year would result in wheat with weak growing characteristics. U.S. scientists believed that a new cross needed a “rest” period to store energy before it could be used for further breeding or for commercial growth.⁶² For this reason, the U.S. scientific community believed shuttle breeding was bad practice. H.K. Hayes, a prominent wheat breeder at UMN under whom Borlaug studied, admonished Borlaug for shuttle breeding.⁶³ Hayes told Borlaug shuttle breeding went against the fundamentals of wheat breeding, and he was incredulous that Borlaug would try something that U.S. scientists had established as scientifically unsound.

⁵⁸ Ibid., 7.

⁵⁹ These rust races in the Bajío were important for improving Mexican wheat production, but there was little transfer of rust from the Bajío to Northwest Mexico or the U.S. Ibid.

⁶⁰ Stakman, “Development of Stem Rust, 1937,” 6; Borlaug, “Wheat Breeding and Its Impact on World Food,” 6; “William C. Cobb Interview of Norman E. Borlaug,” 58.

⁶¹ The MAP pushed these seeds on farmers more quickly in an effort to prove to skeptical Mexican farmers and officials that the MAP could bolster Mexican wheat production rapidly.

⁶² Conventional breeders also believed growing more than one plant generation a year would produce plants that would lose key plant characteristics. Ibid.; Caroline Schneider, “Celebrating 100 Years of Dr. Norman Borlaug,” *Alliance of Crop, Soil, and Environmental Societies*, March 6, 2014, <https://dl.sciencesocieties.org/publications/csa/articles/59/3/4>, accessed February 16, 2019.

⁶³ “William C. Cobb Interview of Norman E. Borlaug,” 188.

Borlaug was open to shuttle breeding because he had evidence that *agrónomos* had already deployed the practice of growing two generations in one year in Mexican breeding programs. In Borlaug's memoir, he describes how RF scientists were competitive with Eduardo Limón, a government scientist in charge of the national hybrid corn program unconnected to the MAP. Borlaug describes how Limón also had the "best wheat program" in Mexico in the 1940s.⁶⁴ Limón supported the work of Antonio Marino, a recent graduate from the Universidad Autónoma Agraria Antonio Narro located near Saltillo, Coahuila in northern Mexico. Borlaug describes how Marino started "a reasonably good wheat breeding program" in León, Guanajuato in which he grew "two crops generations a year."⁶⁵ Thus, Borlaug clearly knew that *agrónomos* grew multiple generations of wheat each year without deleterious effects. Marino, under the tutelage of Limón, was already practicing one innovative aspect that came to define shuttle breeding, before Borlaug's arrival. Borlaug thoroughly vetted shuttle breeding and reified the practice of growing two generations a year as scientifically sound amongst the U.S. scientific community. This novel scientific practice in Mexico was adopted by the MAP and allowed scientists to test thousands more varieties of wheat per year and accelerated the development of new wheat varieties, allowing the MAP to release new wheats in just five years, and if aggressive, in two or three years.

John G. Harrar, the director of the MAP (1943-1953) and eventual president of the entire RF (1961-1972), recounted how the environmental laboratory of Mexico was ideal for testing wheats from around the world, and this revealed unique characteristics that could be bred into the MAP's wheats, saying "it is one of the best areas in the world to breed wheat" due to its "varied" environmental conditions.⁶⁶ The MAP's treatment of Mexico as an environmental laboratory led to many fortuitous discoveries about Asian semidwarfs: semidwarf genes in Norin 10-Brevor were accompanied by another "group of genes, perhaps partially linked, that increased the number of fertile florets per spikelet, and also increased the numbers of tillers per plant."⁶⁷ The increase in florets and tillers meant each wheat plant could yield even more grain than scientists had anticipated. Even if semidwarf wheat had not solved the problem with lodging, the increased florets meant semidwarf wheat would outyield conventional wheat.

MAP scientists also discovered universal qualities in their breeding work which were used to create wheats that could be grown anywhere in Mexico or globally. The most important of these discoveries was photoperiod insensitivity in wheat. The

⁶⁴ Borlaug, "N.E.B.'s Autobiography OEE Part 1," 32.

⁶⁵ Ibid.

⁶⁶ "Memorandum of Understanding Between the Secretaria de Agricultura y Ganaderia and the Rockefeller Foundation in Regard to the Establishment of a 'Centro Internacional de Maíz y Trigo,'" 1968, 4, Elvin C. Stakman papers, Box 4, Folder 2, UMN.

⁶⁷ Norman E. Borlaug, "The Green Revolution: Can We Make It Meet Expectations?" *Proceedings of the American Phytopathological Society* 3 (1976), 12.

MAP's expansive experiments revealed that "in the hormone system someplace, without having a certain number of hours of daylight, [wheat] won't trigger off the change from the vegetative to the reproductive phase."⁶⁸ The Bajío and Sonora experienced different amounts of daylight during their respective wheat growing seasons, and shuttle breeding allowed the Mexican environment to screen MAP wheats for photoperiod insensitive varieties that could be grown anywhere in Mexico. Borlaug described photoperiod insensitivity as a "fundamental discovery" that had been "long overlooked" by U.S. scientists.⁶⁹ While Borlaug would describe this discovery as "serendipity" it was actually a result of a protracted MAP strategy to aggressively breed new wheats in the environmental laboratory of Mexico and allow this environment to forge novel seed technology with universal growing characteristics that could be transported from Mexico to any wheat growing region in the world. Borlaug described how the development of wheat that grew universally in Mexico "wasn't purely accidental. It may have looked like it was. But very early we recognized that we were dealing with something that was rather fundamental."⁷⁰ The MAP marked a continuation of the strategy of *agrónomos* who were already leveraging Mexico's environmental diversity in their agricultural experiments.

The MAP also relied heavily on the early wheat breeding work and germplasm collection of another *agrónomo*, Edmundo Taboada. Taboada had studied under Stakman in the 1930s at UMN, and he was influential in shaping the Mexican government's directive that the MAP should make disease, specifically wheat rust, a "top priority" of the MAP.⁷¹

⁶⁸ "William C. Cobb Interview of Norman E. Borlaug," 55-56.

⁶⁹ *Ibid.*, 57.

⁷⁰ *Ibid.*

⁷¹ E.C. Stakman, "Report on Agricultural Activities in Mexico, 3 Feb to 20 May 1943," Record Group 1.2, Series 323, Box 10, Folder 60, RAC.



Figure 1. Edmundo Taboada

A major impediment to the growth of professional agricultural science in Mexico was a lack of institutional support for experiment stations and extension efforts in the early twentieth century. The Mexican government addressed this through the creation of ten experiment stations dispersed across Mexico under the Office of Experimental Stations (OCE) in 1940.⁷² Taboada directed the breeding and research directives of the OCE which included work on both staple and export crops like wheat, corn, beans, rice, sesame, cotton, sugar, olive, potato, hemp, and guayule.⁷³ Most importantly, Taboada actively acquired global wheat seed technology, including Marroqui (from Tunisia/France) and Mentana (from Italy) to test in northern Mexico. Taboada acquired and identified Marroqui wheat for use in Mexico because it was “quite resistant” to rust, but it was lower yielding, did not do well under heavy fertilization, and it produced inferior flour for commercial baking.⁷⁴ The MAP crossed Marroqui with the Newthatch, created by scientists at UMN, for its high-yield and high-quality flour characteristics, and it enhanced rust resistance further.⁷⁵

⁷² Ana Barahona and Francisco J. Ayala, “The emergence and development of genetics in Mexico,” *Nature Reviews Genetics* 6 (2005), 862.

⁷³ Ibid.

⁷⁴ Ibid.

⁷⁵ Newthatch was a premier wheat used in breeding programs and direct planting in the U.S. hard red spring wheat region because it produced high quality flour. Newthatch was created in the U.S.

Agrónomos and RF scientists produced three crosses from Marroqui and Newthatch through shuttle breeding, and one of these early crosses, Yaqui 49, became a foundational wheat seed in the creation of the universal seeds of the Green Revolution due to the rust resistance from Marroqui.

Taboada also identified Mentana before the arrival of the MAP, and he saw its potential for use in Sonora in the 1930s.⁷⁶ Taboada began a breeding and testing program on the experiment station of Rodolfo Elías Calles, the son of the former president of Mexico, Plutarco Elías Calles. His work began testing at least thirty to forty wheat varieties for high commercial-qualities in Sonora.⁷⁷ Taboada's goal was to replace low quality Barrigón wheats, only suitable for less profitable food products like soda crackers, with a wheat suitable for bread production. Taboada had already put in the legwork to acquire, test, and identify Mentana as breeding material for farmers in the Northwest, and the MAP completed the testing Taboada left unfinished due to health problems. Mentana showed good milling and baking qualities as well as a potentially unique ability to resist rust given its better performance during the rust outbreaks in Mexico between 1939 and 1941. The MAP combined Mentana with Kenya, to further enhance rust resistance, and produce Kentana which also became a foundational wheat in the creation of the Green Revolution.

Ignacio Narvaez and the Globalization of the Green Revolution

Well before MAP scientists first released semidwarf wheat seed technology between 1961 and 1964 in Mexico, Borlaug stepped away from the MAP's wheat program. In the late 1950s, Borlaug detached from his work in Mexico and spent his time as an itinerant scientist speaking with governments in the Global South about the potential of semidwarf wheat seed technology.⁷⁸ When Borlaug left the MAP's wheat program, semidwarf wheat seed technology yielded well, but it still had poor milling and baking qualities which prevented its release for commercial growth.

By the late 1950s, Mexican scientists were responsible for the majority of the scientific work and now the leadership of the MAP's wheat program as the seeds of the

hard red spring wheat region using wheat seed technology from Crimea, India, Italy, and Russia. Bayles, "Classification of Wheat Varieties Grown in the United States in 1949," 86; "Development of New Wheat, Renewed Fight on Barberry Relied on to Conquer Rust," Undated, Elvin C. Stakman papers, Box 1, UMN; E. R. Ausemus et al., "Newthatch Wheat." *University of Minnesota Agricultural Experiment Station*, 1944, Technical Bulletin 166, Access November 1, 2020, <https://core.ac.uk/download/pdf/222896638.pdf>.

⁷⁶ Borlaug, "N.E.B.'s Autobiography OEE Part 1," 3.

⁷⁷ Ibid.

⁷⁸ Borlaug also led the Inter-American Wheat Improvement Program, and Wellhausen led an Inter-American Corn Improvement Program. Both were precursors to CIMMYT.

Green Revolution were produced. Evagelina Villegas led the MAP's chemical laboratory that refined semidwarf wheats, and her scientific innovations in testing wheat helped the MAP save years of breeding time. Villegas ground small amounts of flour from the MAP's experimental crosses to bake miniature loaves of bread to test for quality. Her scientific work was indispensable for raising the commercial quality of wheat in Mexico; when she rejected a wheat variety for inferior quality, the MAP stopped breeding it. Villegas was on the forefront of chemical analysis of wheat, and she built upon the work of another Latin American wheat expert, Enrique Klein of Argentina.⁷⁹ Borlaug describes how Villegas greatly condensed the time it took to perform chemical analysis of wheat by adopting many of Klein's "shortcuts" which were also copied wholesale by the prominent U.S. seed company, DeKalb.⁸⁰

In the field, Reyes Vega, an uneducated farm laborer would rise into one of the most innovative wheat breeders in the world. Not only did his breeding speed surpass Borlaug's, but his technical innovations to crossbreeding wheat saved the MAP thousands of hours of labor.⁸¹ Before Vega, MAP scientists, both from Mexico and the U.S., emasculated wheat by pulling the wheat's pollen sacs off one-by-one, a time-consuming process that required technical precision. Vega experimented with this technical process of crossbreeding wheat, and he discovered that wheat breeders could clip the glumes (covering the ovary and pistil) off of the wheat and that all of the wheat's pollen sacs could be pulled off at once instead of one-by-one. According to Borlaug, "Reyes Vega's discovery saved us man-years of effort. Before, we'd picked out each of the male parts one by one with tweezers; now, we yanked them all out together."⁸² Vega's innovation enabled the MAP to crossbreed thousands of varieties of wheat a year with limited resources, whereas in most breeding stations in the U.S. a breeder accomplished just hundreds.⁸³ As the Green Revolution was forming in the 1960s, Vega began to train scientists that visited the MAP to learn about largescale breeding programs, and he helped trained these scientists on how best to replicate the MAP's wheat program: Borlaug celebrated Vega's abilities in teaching scientists of the Global South how to implement their own Green Revolutions saying, "if you want to know how to run a breeding program, follow Reyes Vega and talk to him. You'll learn more that way than from me or the other scientists."⁸⁴

⁷⁹ "William C. Cobb Interview of Norman E. Borlaug," 288-290.

⁸⁰ *Ibid.*, 11.

⁸¹ Noel Vietmeyer worked on an autobiography of Borlaug and documented important information on the role of Mexicans in the MAP's breeding work. Noel Vietmeyer, interview with John Garnett, January 24, 2017, Fairfax, Virginia.

⁸² Noel Vietmeyer, *Borlaug: Volume 2, Wheat Whisperer 1944-1959* (Lorton: Bracing Books, 2009), 126.

⁸³ Noel Vietmeyer, interview with John Garnett, January 24, 2017, Fairfax, Virginia.

⁸⁴ Noel Vietmeyer, *Borlaug: Volume 3, Bread Winner 1960-1969* (Lorton: Bracing Books, 2010) 37.

Finally, the *agrónomo* Ignacio Narvaez navigated the MAP's wheat program as it improved semidwarf wheat for release to Mexican farmers between 1961-1964, before being exported to India and Pakistan in large quantities in the mid-to-late 1960s that gave birth to the Green Revolution. Narvaez led the MAP's wheat program between 1959 and 1965, and he was at the helm when it completed breeding the first semidwarf wheat seed technologies, Pitic 62 and Penjamo 62, which the MAP released to Mexican farmers between 1961 and 1962. Under Narvaez, the MAP's wheat program released four additional semidwarf wheat seed technologies in 1964 as well. It was under Narvaez's leadership that these six semidwarf wheat seeds became the foundation for a global Green Revolution with wheat as its centerpiece.⁸⁵

⁸⁵ In the presentation speech for Borlaug's Nobel Peace Prize for the Green Revolution, the chairman of the Nobel Committee described how Borlaug, "through his work in the laboratory and in the wheat fields, has helped to create a new food situation in the world and who has turned pessimism into optimism in the dramatic race between population explosion and our production of food." She also described how "this occasion is neither the time nor the place to give a detailed account of Dr. Borlaug's great results in wheat research during the last twenty-five years. But it has been established beyond doubt that his efforts have made possible an unequaled increase in wheat production and an improvement in quality that have postponed a crisis that a great many scientists have predicted would be the result of the growing gap between the population explosion and food production." The Nobel Committee placed wheat at the center of the Green Revolution and pointed out its use as a model for other Green Revolution crop programs, especially rice. "Award ceremony speech: Presentation Speech by Mrs. Aase Lionaes," *Nobelprize.org*, 1970, <https://www.nobelprize.org/prizes/peace/1970/ceremony-speech/>, accessed August 20, 2022.



Figure 2. Ignacio Narvaez Highlights Height Differential of Conventional and Semidwarf Wheat

Narvaez navigated the MAP through a crucial moment in 1963 when the MAP transitioned into an international non-profit, the Centro Mejoramiento de Maíz y Trigo, based in Mexico (CIMMYT).⁸⁶ Narvaez led Mexico's national wheat breeding work through the Instituto Nacional de Investigaciones Agrícolas (INIA) and became a principal contributor to CIMMYT's wheat work. Throughout his career, Borlaug reiterated the importance of Mexicans in the creation of the Green Revolution, and in his Nobel Prize Lecture Borlaug made clear that,

⁸⁶ CIMMYT became one of the foundational agricultural research centers that led to the Consultative Group on International Agricultural Research (CGIAR), a network of similar agricultural research centers that have controlled the agricultural research agendas in much of the Global South during the second half of the twentieth century.

When the Nobel Peace Prize Committee designated me the recipient of the 1970 award for my contribution to the “green revolution”, they were in effect, I believe, selecting an individual to symbolize the vital role of agriculture and food production in a world that is hungry, both for bread and for peace. I am but one member of a vast team made up of many organizations, officials, thousands of scientists, and millions of farmers.⁸⁷

Borlaug described semidwarfs as “Mexican dwarf varieties” to emphasize the importance of Mexico in the Green Revolution.⁸⁸ Moreover, Borlaug received his Nobel Peace Prize principally for the increase in wheat production that India and Pakistan achieved in the mid-1960s when they first imported semidwarfs from Mexico. In 1964, the Pakistan government imported 440 pounds of MAP wheat seed technology and subsequent trials demonstrated Penjamo 62, Sonora 64, and Lerma Rojo 64 were the best adapted seeds to boost yields in Pakistan. Also in 1965, Pakistan purchased 250 tons of Penjamo 62 and 100 tons of Lerma Rojo 64 from the government controlled seed distribution organization in Mexico, Productora Nacional de Semillas (PRONASE).⁸⁹ This south-south seed purchase was the largest in history of any kind at the time, and Narvaez personally escorted the thirty flat-bed trucks filled with seed from Sonora to San Pedro, California in the middle of the Watts riots to be shipped to South Asia.⁹⁰ Narvaez would also lead Pakistan’s wheat improvement program in the 1960s working closely with Pakistani farmers and scientists to create Pakistan’s Green Revolution. The role of Mexican actors in the scientific breeding work and training programs that lubricated the wheels of the Green Revolution suggest historians should look at the south-south spread of the Green Revolution. The U.S.-based RF was critical in facilitating the spread of the Green Revolution, but Mexican actors were central to important scientific exchanges, and future scholarship should seek to center actors from the Global South to better understand the scientific breeding work and dissemination of scientific knowledge globally.

⁸⁷ Borlaug, “Norman Borlaug Nobel Lecture: The Green Revolution, Peace, and Humanity.”

⁸⁸ Ibid.

⁸⁹ At the same time, India’s wheat program under the RF’s Glenn Anderson purchased 250 tons of the MAP’s semidwarf wheat seed technology from PRONASE. “William C. Cobb Interview of Norman E. Borlaug,” 26.

⁹⁰ There were numerous other complications in this seed sale besides the Watt’s riots. For example, in Pakistan’s insurance policy they had clauses that read “act of God” while Mexico required it read “act of nature.” Ultimately, the Pakistan version of the contract read “God” and the Mexican version read “nature.” Moreover, this seed shipment occurred during the Indo-Pakistani War of 1965. As the ship neared South Asia in August 1965, the shipping company, American President Lines, offloaded Pakistan’s seed shipments in Singapore and chartered a separate boat to deliver the seed to Karachi. There was fear that had the ship stopped in either Pakistan or India with both seed shipments, then they would have been confiscated due to the war. Noel Vietmeyer, *Our Daily Bread: The Essential Norman Borlaug* (Lorton: Bracing Books, 2011), 207-210.

Conclusion

When Borlaug received the Nobel Peace Prize for his role in the creation of the semidwarf wheat seeds that gave rise to the Green Revolution in 1970, Aase Lionaes described how Borlaug, “more than any other single person of this age...helped to provide bread for a hungry world” through the creation of semidwarf wheat.⁹¹ Popular accounts that followed depicted Borlaug as a crusader working alone in the fields, a solitary genius possessed with an insatiable drive to “feed the world” and bring it peace in the process.⁹² In addition to the Nobel Peace Prize, Borlaug would also win the Presidential Medal of Freedom in 1977 and the Congressional Gold Medal in 2007; only seven people in the world have achieved this trifecta of accolades which includes Nelson Mandela, Dr. Martin Luther King Jr., and Mother Teresa.⁹³ Borlaug became the singular embodiment or “brand hero” of the Green Revolution and is still known today as the father of the Green Revolution. Today, policymakers and philanthropists, from Barack Obama to the Bill and Melinda Gates Foundation, evoke the Green Revolution as a successful model to combat rural poverty, and Borlaug is celebrated as an international hero.⁹⁴

Given the popularity and reputation of Borlaug following his Nobel Peace Prize, it is no surprise that both popular and academic historical scholarship placed the U.S. at the center of the historiography of the Green Revolution. In historical hindsight, however, this article has demonstrated that privileging the U.S. in the creation and spread of the Green Revolution obscures the global process and scientists that created semidwarf wheat. Rather than view the Green Revolution as a case of technology transfer (seeds) from center to periphery, from the U.S. to the less “advanced” regions of Africa, Latin America, and Asia, this paper argues that historians should strive to look at the global contributions, connections, and exchanges that allowed the Green Revolution to spread in a multi-directional manner globally.

A historical seed pedigree chart of one the foundational wheat seeds of the Green Revolution, Lerma Rojo 64, allows for better visualization of the global contributions that gave rise to the Green Revolution. As can be seen in the chart in Appendix

⁹¹ “Award ceremony speech: Presentation Speech by Mrs. Aase Lionaes.”

⁹² Following Borlaug’s receipt of the Nobel Peace Prize, Bickel wrote the first biography of Borlaug that portrayed him as the hero of the Green Revolution. In 2006, Leon Hesser’s biography, the most complete biography of Borlaug to-date, described Borlaug as the “man who fed the world.” Lennard Bickel, *Facing Starvation: Norman Borlaug and the Fight Against Hunger* (New York: Reader’s Digest Press, 1974); Leon Hesser, *The Man Who Fed the World: Nobel Peace Prize Laureate Norman Borlaug and His Battle to End World Hunger* (Dallas: Durban House Publishing Company, 2006).

⁹³ “Dr. Norman E. Borlaug Statue,” *Architect of the Capitol*, accessed January 15, 2022, <https://www.aoc.gov/explore-capitol-campus/art/dr-norman-e-borlaug-statue>.

⁹⁴ James Sumberg, Dennis Keeney, and Benedict Dempsey, “Public Agronomy: Norman Borlaug as ‘Brand Hero’ for the Green Revolution,” *Journal of Development Studies* 48:11 (2012), 1587.

A, it is impossible to define a “center” of scientific production that led to creation of semidwarf seeds when it was the result of a global process. The wheat that gave rise to the Green Revolution came from every inhabited continent and reflected five hundred years of breeding work conducted by both farmers and scientists. While the semidwarf gene in Lerma Rojo derived from Korea, Japanese scientists spent over forty years testing and breeding higher quality characteristics into it using U.S. and Crimean wheats. In the 1950s and 1960s, the MAP added higher quality characteristics and disease resistance into Asian semidwarf wheats using biotechnology from the Ukraine, Italy, Kenya, Australia, Morocco, North America, and other parts Europe. It was the novel ideas and experimentation of *agrónomos* like Ricardo Manso León, Edmundo Taboada, and Ignacio Narvaez and plant pathologists like E.C. Stakman and Norman E. Borlaug in the unique environmental laboratory of Mexico that led to the creation of universal semidwarfs that made the Green Revolution possible.

Abstract

In 1943, the Rockefeller Foundation (RF) and Mexican government collaborated in the creation of the Mexican Agricultural Program (MAP) to boost the production of hybrid corn and wheat in Mexico. The MAP utilized a top down strategy in which it sought to provide largescale, affluent farmers with new seed technology to boost staple crop production intended for urban consumers that underpinned industrialization, principally in the middle- and upper-classes. The MAP's wheat program served as the model for the Green Revolution in the Global South beginning in the 1960s, and policymakers and philanthropists continue to evoke it today as a successful effort to combat rural poverty despite mixed results.

During the Green Revolution, farmers produced millions more tons of food using semidwarf wheat seed technology which possessed short, stiff straw that allowed farmers to transcend the biological constraints of conventional wheat. In particular, this wheat prevented a problem called lodging which meant farmers could now apply massive amounts of inorganic fertilizers, the byproduct of natural gas and oil production, to wheat fields. While the historiography of the Green Revolution credits the U.S. and RF with this innovation, the semidwarf characteristic derived from a Korean wheat seed technology that underwent protracted testing in Japan in the early twentieth century. Moreover, *agrónomos*, Mexican agricultural scientists, also played a prominent role in the MAP's wheat breeding program which gave rise to the Green Revolution. In particular, the treatment of Mexico as an environmental laboratory gave rise to an innovative practice called shuttle breeding which revealed unique characteristics in wheat and allowed MAP scientists to produce universal wheat. Mexico's environmental diversity meant a wheat that could grow widely in Mexico was easily adaptable around the world, especially the Global South.

Keywords: Green Revolution, Semidwarf Wheat, Mexican Agricultural Program, Norin, Norman Borlaug, Rockefeller Foundation

Historical Pedigree Chart: Lerma Rojo 64

