The wide adaptation of wheat: Expanding the Rockefeller Foundation's international agricultural research program

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In my dissertation research, I study the history of studies on wheat adaptation to climate, beginning in the 1950s and through the 1970s. In the 1960s, Norman Borlaug, while working for the Rockefeller Foundation (RF) in Mexico, popularized the concept of wide adaptation—meaning a crop that gives high yields and is stable across different environments. Before Borlaug popularized wide adaptation, most scientists believed the crops were best suited to the location and conditions that they were developed in. Borlaug and the RF's international wheat program challenged this conventional wisdom while expanding their wheat program in Latin and South America, South Asia, and the Middle East. Because the history of wheat improvement is closely tied to other RF programs in maize and rice, my research also examines these crop research programs.

I spent three weeks at the Rockefeller Archive Center in April and May 2014. While there, I focused on three topics: the RF's international wheat programs in the 1960s (focused on the office in Mexico), the RF's Indian agricultural program in the 1950s and 60s, and RF's international wheat programs in the 1970s (focused on the Middle East). For the RF's international wheat programs in the 1960s, I was interested in the progression from the Mexican Agricultural Program to the Inter-American Food Crop Improvement Program, then to the International Center for Corn and Wheat Improvement, to eventually the International Maize and Wheat Improvement Center (CIMMYT). I examined records from the project files (RF, Record

Group 1.2, Series 300D and 323, Record Group 1.3, Series 105), administration, program and policy files (RF, Record group 3, Series 915 and 923), Mexico field office (RF, Record Group 6.13, Series 1), officer diaries (RF, Record Group 12), oral histories (RF, Record Group 13), and the RF Agricultural Science Program Annual Reports.

The second part of my research focuses on the RF's involvement in Indian maize and wheat improvement. Towards this end, I used project files (RF, Record Group 1.2, Series 464D, and Record Group 1.6, Series 464D) and the New Delhi field office records (RF, Record Group 6.7). Finally, I explored the RF's expansion into wheat research in the Middle East in the 1970s, utilizing again the project files (RF, Record Group 1.3, Series 105) and some recently added archival material from the Ankharka, Turkey, field office (RF, Record Group 6, Series 19).

The Rockefeller Foundation's Mexican Agricultural Program

The Rockefeller Foundation began supporting agricultural research in the early 1900s.[1] Many of the RF's programs at this time aimed to apply scientific research to social problems such as public health and population. In 1943, The RF entered into an agreement with the Government of Mexico that would be known as the RF's Mexican Agricultural Program (MAP). Previously, the RF had sent a group of scientific advisors to Mexico to survey the possibilities for an agricultural program in Mexico. Elvin C. Stakman, Richard Bradfield, and Paul Mangelsdorf, all professors of agricultural science, went to Mexico in 1941 and developed a set of recommendations for a "technical assistance" program of the RF. Much has already been written about the various facets of the RF's MAP.[2] I will examine the internationalization of the MAP, and in particular, the conversation over crop adaptation to climate.

The initial motivation for foreign involvement in agriculture was modernization of the state through commercialization of agriculture and consolidation of agricultural labor.[3] To this end, the RF aimed to bring agricultural expertise to problems facing Mexican agriculture, such as breeding varieties of wheat that were resistant to stem rust and more viable for commercial agriculture.[4] The MAP initially focused on maize, beans, and wheat improvement for Mexican conditions. Improved wheat varieties, under the supervision of Norman Borlaug, were released in 1949, and by 1957 these new varieties constituted 90% of Mexican wheat acreage.[5] Again, many of the important details of the MAP are well-documented in historical literature, therefore the next sections will focus on some of the scientific aspects of the MAP and how it became a model for international agricultural development.

Lewontin wrote that scientists in the MAP initially worked without any formal theory of agricultural development, but rather from the pragmatic angle of scientific agriculture, popular in the US at that time.[6] Most of the RF's agricultural staff was a product of the US land grant system.[7] This pattern on land-grant type organization (based on the linear model of research to extension) is seen throughout RF programs in Mexico, India, and the Philippines.

According to Dalhberg, a major scientific innovation of the MAP was the discovery that improved crops for the semi-tropics needed to be developed from genetic stocks in the tropical, rather than temperate (US and Canadian) zones. This was because wheat and maize from the US and Canada were generally poorly-adapted to Mexican conditions. Borlaug ultimately discovered that wheat varieties from Mexico were photoperiod insensitive, meaning that they could be grown under a variety of altitudes and latitudes, unlike Canadian and American wheats. In his oral history J. George Harrar, who started the MAP and later became president of the RF, stated:

> Unfortunately, most scientific advances most directly benefit the particular geographic area in which they originated. This is especially true in the agricultural sciences. Of course, many basic principles are discovered which can be useful on an international front, on a broad front, but the application of those principles depends upon local climatic conditions and on many other factors.[8]

Harrar's statement reflects a common view at that time, and one that Borlaug would challenge with the introduction of widely adapted wheat varieties.

Harrar also pointed out two other principles of the MAP: collecting foreign germplasm and testing varieties under controlled conditions. He noted, "one of the things we did was bring together the varieties of crop plants on which we were working from all of those parts of the world where climatic conditions had reasonable similarities... you don't know what to throw away until you get them together and test them."[9] Secondly, Harrar stated that, "the plant itself tells you how many bushels you will get per acre, and the only way you can find that out is by growing it under controlled conditions, theory to the contrary."[10] Stakman echoed these principles in his own statement that, "wheat and corn and beans are grown under many different conditions and the varieties suitable in one area may not be suitable in another; these facts must be determined by experimentation."[11] These two principles—a diverse germplasm base and widespread testing—became a standard for the RF's international agricultural programs.

Improved vs. traditional varieties of maize

The MAP's maize program was not as successful as the wheat program, nonetheless maize remained a main area of the research in the RF's MAP (and later organizations in Mexico based on the MAP). Many scholars have discussed reasons for the lack of adoption of the RF's maize varieties in Mexico. A common theme of these analyses is that modern maize was developed to be fertilizer responsive under irrigated conditions. In contrast, the majority of maize farmers in Mexico did not use irrigation, which also made fertilizer more risky and less cost-effective. Some scholars, but particularly Lewontin, point to this as a social bias by the RF scientists.

The strategy of breeding maize for irrigated, highly fertilized conditions prevailed until the late 1960s, when criticisms of the style of research became more widespread. In the late 1960s the RF launched the controversial "Project Puebla," an extension-based project to disseminate modern maize varieties to rainfed farmers, which was largely unsuccessful due to the lack of adaptation of maize to the rainfed conditions.

Edwin J. Wellhausen, a corn geneticist for the MAP from its beginning, and director starting in 1951 (later director of CIMMYT), understood some of the challenges faced by marginal maize farmers.[12] In his oral history, he explained how maize farmers in Mexico different from maize farmers in the US. He stated,

> In the United States we think about producing varieties that yield the most in average years, and if we get caught with an abnormal season or an early frost... we'll hope to make up for it in succeeding years. But not here [Mexico]. They [farmers] selected very hard for those things that produced under very adverse conditions, regardless of how much they yield. They weren't interested in maximum yield, but they were interested in getting something every year.... They had selected for adaptation to the extremes of climate, rainfall.[13]

Although Wellhausen's assessment is generally accepted as true of plant selection and adaptation in marginal conditions, the Green Revolution research strategy would continue to focus on maximum yield under ideal conditions.

Internationalizing the MAP

Starting as early as 1950, the RF began a series of international agricultural programs based on the MAP. Minutes from the 1950 meeting of the RF's International Health Division recorded that, "Five years ago we got into agricultural development in Mexico... The success and

interest in it would in itself raise the question whether The Rockefeller Foundation should, as a general undertaking, continue to do that kind of program" [emphasis original].[14] In 1951, Harrar stated that the MAP could be expanded to Asia.[15] RF administrators including Harrar were interested in long-range planning, rather than short-term support, for programs similar to the MAP in Asia. He saw India and the Philippines in particular as obvious choices for expanding their agricultural program into Asia.

In fact, the first international agricultural programs based on the MAP starting in South America, with Columbia starting in 1950, and in Chile starting in 1955. Then in 1958, the inter-American corn improvement program started, followed by the inter-American wheat improvement program. Throughout the 1950s and 1960s, the RF's international agricultural programs rapidly proliferated. The RF sent agricultural officers to several countries in South America and Asia, but they also developed a network of cooperative crop testing programs through South America, the Middle East, and Asia. These cooperative programs were a means for the RF to institutionalize their international research agenda. Many, including Stakman, would view the internationalization of the MAP to Latin America and elsewhere as a natural progression due to its success.[16]

Inter-American Food Crop Improvement Program

The RF's own first official international cooperative program was the Central American Corn Improvement Program.[17] In 1954, the RF sent Harrar, Stakman, and Sterling Wortman through Central America to survey the possibility of an international cooperative maize testing program.[18] The team recommended that the RF work with El Salvador, Hondura, Nicaragua, Costa Rica, and Panama. Based out of the offices in Mexico and Columbia, the RF began the Central American Corn Improvement Program in 1954. The goal of the program was to test maize varieties, which had already been exchanged between Columbia and Mexico, "the see whether some of them may be used at once in the cooperating countries."[19] Also in 1954, the Indian government contracted two maize scientists, E.J. Wellhausen and U.J. Grant, from the RF to survey India's research and development system and advise on collaboration between India and the RF. At that time, Wellhausen directed the MAP, and Grant led the RF Columbian Agricultural Program's (CAP) corn improvement program.

Then starting in 1956, MAP and CAP started a world-wide maize testing program that extended to several more countries in South America and also India, Indonesia, and the

Philippines.[20] The world-wide program aimed to evaluate the "adaptability and genetic value of specific material throughout the world, help breeders learn what is available, and help the germ plasm banks to fill seed requests intelligently."[21] That same year, the RF and Government of India signed a memorandum of understanding aimed at improving secondary education in agriculture and focusing on three cereal crops: hybrid corn, sorghum, and millet. On March 8, 1957 Ralph W. Cummings, a soil scientist, arrived in India as field director for the Rockefeller Foundation, and U.J. Grant as assistant field director and director of maize breeding.[22]

In 1959 the RF institutionalized its international maize program as the Inter-American Food Crop Improvement Program, led by Wellhausen.[23] The program initially focused on maize but later included other crops such as wheat. This program aimed to apply the Columbian, Chilean, and Mexican agricultural programs more broadly throughout the western hemisphere. By 1960 the Inter-American Food Crop Improvement Program grew to include wheat, which would soon become its major focus. The RF established this program for two additional reasons, both internal and external. Internally, the RF's Mexican program was moving towards an administrative transfer to Mexican scientists, which started in 1960 with the appointment of Ignacio Narvaez Morales as director of the MAP's wheat improvement program.[24] Because of this, the RF decided to establish Inter-American Food Crop Improvement Program so that they could continue to operate internationally in Latin and South America. Secondly, the RF responded to demand from attendees at the Fourth Latin-American Conference of Agricultural Scientists in 1958. Wheat scientists at this meeting agreed to establish an inter-American cooperative yield test for wheat, similar to the Central American Corn Improvement Program. RF scientists, specifically Norman Borlaug, would coordinate this program out of Mexico.

In 1961, the administrative portion of the MAP was terminated and the National Institute for Agricultural Investigations (INIA) was formed to carry out the MAP's operations. According to Jennings, the Inter-American programs floundered so the RF began looking for new institutional support for the program. Additionally, many of the RF scientists were not happy working at the INIA due to the budget and political tensions. So in 1963, the RF partnered with the Ford Foundation and Government of Mexico to form the International Center for Corn and Wheat Improvement, headquartered in Chapingo, Mexico. The RF still provided funding to the INIA but built a new scientific complex to house the RF researchers.[25]

International Center for Corn and Wheat Improvement

The International Center for Corn and Wheat Improvement (the Center), as its name suggests, focused on international research programs for corn and wheat. Its overall goal was, as the Secretary of Agriculture and Livestock, Ing. Julian Rodriguez Adame, "to aid, on an international scale, in the improvement of materials and methods for the production of corn and wheat by obtaining improved varieties and by applying breeding techniques to achieve greater protection against insect pests and diseases as well as destructive climatic effects."[26] The main goals of the wheat program included developing new varieties of wheat that were rust resistant and also "high-yield, widely-adapted."[27] For corn, the goals were to collect and distribute maize germplasm, to breed varieties resistant to disease, to develop varieties for high fertility conditions, and "to develop corn varieties insensitive to day length and temperature, thereby increasing adaptability."[28]

At this time, Borlaug and others began to popularize wide adaptation as a breeding goal for cereal crops. Borlaug had already discovered, through the cooperative wheat trials, that several of the varieties of wheat from Mexico and Columbia could be successfully grown in other countries in the Middle East and South Asia. RF scientists found that maize, however, was not as successful abroad. It has a more narrow range of adaptation, likely due to its sensitivity to day length.

By 1965, it was more and more clear that wheat would be the main focus of the Center. By then, the RF had become involved in the Indian wheat improvement program, and Ignacio Narvaez was contracted by Pakistan and the Ford Foundation to assist with their wheat program. Lewis M. Roberts, an Associate Director of Agricultural Sciences at the RF, wrote in a 1965 that a main asset of the Center was their four wheat breeders: Borlaug, R. Glenn Anderson (recently hired by the RF to work in India), John W. Gibler, and Charles F. Krull.[29] Roberts viewed the location of Mexico as an asset as well. He wrote, "The broad range of ecological conditions in that country provide a highly favorable natural setting for corn and wheat improvement work applicable to a broad belt of the globe, especially in the tropical latitudes."[30] Roberts, among others, saw the potential to expand the RF's international wheat program based on widely adapted germplasm developed and tested in Mexico. The International Center for Corn and Wheat Improvement became the International Maize and Wheat Improvement Center (CIMMYT) in 1966.

In the 1940s and 50s, the MAP aimed to collect foreign germplasm and test newly developed varieties under controlled conditions in Mexico. In the 1960s, as the MAP ended and Inter-American Food Crop Improvement Program began, RF scientists added the element of international testing to the equation. This rapidly expanded into RF- and CIMMYT-sponsored programs into Asia and other countries. Further, the Rockefeller Foundation became involved in rice research in the Philippines in 1959. This program was also based on the MAP. It retained the goal of developing broadly adapted varieties that could be distributed to developing countries, this time with rice instead of wheat and maize.

The international wheat improvement program and coordinated wheat yield trials

This next section will focus on the growth of the Rockefeller Foundation's international wheat improvement program, led by Norman Borlaug starting in 1960. In the late 1950s, RF administrators were eager to get Borlaug into a position of international leadership in wheat research. This had two prongs: training groups of international scientists under Borlaug's direction in Mexico, and expanding the RF's introduction of wheat varieties globally.

Harrar wrote to Borlaug in 1958 that, "It is now timely to begin to intensify international research on small grain improvement in the Americas and its logical leadership to this effort should come out of the cooperative agricultural program in Mexico."[31] Harrar also wrote in 1959 to Jose Vallega of the Food and Agriculture Organization (FAO) that "We now want Dr. Borlaug to operate on a very much more international scale. We would like to support him in an effort to strengthen cereals improvement research throughout the Americas and link these more closely together from the northern to the southern extremes of production areas."[32] Borlaug began working with the FAO to plan a series of international wheat yield trials and to start training young international scientists in Mexico.

In 1960, Borlaug began running international yield trials for wheat. Borlaug became interested at this time in "the possibility of developing varieties with extremely wide patterns of adaptation" due what he considered the theoretical and practical importance.[33] A major goal of the international wheat trials was that a "uniform yield nursery of this type has never been grown previously over this wide on latitudinal and elevational belt and consequently valuable information on varietal adaptation should be forthcoming."[34] He set up the international wheat trials to test the adaptation of wheat in carefully managed trials but under varying geographic conditions.

Borlaug sent wheat varieties to his collaborators who spanned Brail, Peru, the US, Australia, Egypt, and Pakistan. Borlaug had connections in countries, especially in the Middle East, through the FAO and later, through FAO scholars from the Middle East, Africa, Central Asia, and South Asia whom he had trained in Mexico. In 1962 the RF and FAO formally collaborated to start the Co-operative Near East-American Spring Wheat Yield Nursery.

Over the first few years of the international wheat yield trials, Borlaug became more and more excited about the wide adaptation of some wheat varieties. He stated at a 1960 meeting that "wheat is very different from corn in that it appears to be much more flexible in its adaptation to different soils and climatic conditions... Nonetheless, the wheat crop is made up of thousands of different varieties, and this tends to mask or camouflage the true adaptability of certain varieties of wheat."[35] He suspected that photoperiod insensitivity contributed to the adaptability of wheat, and that wheat varieties from the US and Canada were specifically adapted to certain daylight requirements. Traveling through the Middle East in 1960, Borlaug was "amazed to see the wide adaptability of many of the wheat materials" and felt that many of the scientists did not recognize this, due to their lack of experience outside their own country.[36]

In addition to discovering the importance of daylight insensitivity of certain wheats, Borlaug incorporated this trait into what he called dwarf wheat. Dwarf wheats had shorter and thicker straw than traditional wheat varieties. Borlaug came across dwarfing potential through Orville Vogel at Washington State University, who had obtained the wheat variety Norin 10 from Japan. Borlaug began crossing Norin 10 with Mexican wheat varieties in the 1950s, which resulted in a dwarf wheat variety adapted to Mexican conditions. Borlaug also focused on incorporating rust resistance into his new wheat varieties.

Borlaug had a variety of reasons for promoting dwarf wheats internationally. The dwarf wheats could withstand higher levels of fertilizers with falling over and lodging, as traditional varieties were prone to do. Because they could handle more fertilizer, they had a higher yield potential than the traditional tall wheats. Borlaug believed that fertilizers would soon become more available worldwide, and reasoned that, "any breeding program which did not take into consideration a change in levels of soil fertility within the next five years, would be doomed to failure."[37] His primary focus of the international wheat program became developing varieties that could withstand high levels of fertilizer in order to maximize their yield.

Borlaug also anticipated criticisms of the dwarf wheats. He responded to the "belief that

these dwarfs in drought years will be short, that they will produce little or no grain, and that under such conditions what is produced will not be harvestable,"[38] arguing that "the dwarfs now growing in Toluca show none of the weaknesses that had always been predicted for this kind of wheat under dry land conditions."[39] Borlaug's focus on the inputs of irrigation and fertilizer became very important themes for the future of wheat breeding. From the beginning of the RF's international wheat improvement program, Borlaug presented a unified argument that 1) scientists should use higher levels of irrigation, and that 2) dwarf wheat varieties performed equally well in dryland and irrigated conditions to traditional varieties (i.e. they did not do any worse, even in drought years). At the same time, Borlaug was training a cohort of young scholars from the Middle East and other developing countries to bring these ideas back to their home countries, and to form an international scientific network.

In my dissertation I will show how some of Borlaug's ideas, particularly breeding wheat under ideal conditions, became problematic in developing countries such as India in the 1960s. In short, Borlaug's experience in Mexico was based largely on working with irrigated wheat farmers. The Mexican varieties that Borlaug helped release in India immediately benefitted farmers who had access to irrigation, which was only a small proportion of farmers overall. Further, Borlaug relentlessly promoted high levels of fertilizer, even though there was a fertilizer shortage in India. Based on my research on the RF's wheat programs in Turkey and the Middle East, however, I show how the RF's research program evolved to address the special needs of dryland agriculture.

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