Chapter 11
Science, Promotion, and Scandal: Soil Bacteriology, Legume Inoculation, and the American Campaign for Soil Improvement in the Progressive Era

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Introduction

In his 1904 address before the American Microscopical Society, the American plant pathologist Thomas J. Burrill delivered a message that his audience must have been glad to hear: The microscope had been more important than "any other piece of mechanism whatever in promoting and prolonging life."[1] Burrill backed this claim by highlighting the recent discovery of soil microbes, and the evidence that "all nutrition as applied to man seems to be ultimately conditioned upon the activity of certain micro-organisms in the soil." Arguing that "soil fertility and man's virility are closely related," Burrill had found confirmation among the farmers in his native Illinois. Those who lived on poor soils, he observed, "take unconsciously a slower step, require more time in which to transact business, and have less relish for physical or mental activity," while those who live on good soils were part of a "progressive, strong, hopeful, and happy populace."[2] Good soils, he continued, included bacteria that only the microscopists could see, "wonder-working little creatures" that were the "fertility producers [and] advance agents in the making of a farm."[3]

[1] Burrill (1904, p. 426).

[2] Burrill (1904, p. 434).

[3] Burrill (1904, pp. 422–429).

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A key question, then, was how to manage and multiply the beneficial kinds of soil bacteria. Burrill had good news. Thanks to the recent discovery of legumes' ability to fix atmospheric nitrogen through the bacteria found on their root nodules, scientists had unveiled an apparent panacea: packages of pure bacterial cultures known as "legume inoculants." Appearing amid great fanfare in 1904, and distributed widely through the United States Department of Agriculture (USDA), these packages contained millions of nitrifying bacteria that seemed to offer a simple means to improve the quality and quantity of soil bacteria, to enhance soil fertility, and to raise farmers' incomes. Speaking at the peak of the Progressive Era, Burrill's address demonstrated the confidence of the American life scientists who believed the applications of their research could improve society as a whole.[4]

Burrill's address also sheds light on the emerging disciplines of soil bacteriology and applied botany. Earlier notions that tied fertility to the chemical and physical nature of soils had often proven unsatisfactory on scientific and economic grounds. Thus, advances in soil bacteriology, and scientific understanding of soils as living, organic, and interdependent environments became a powerful force in the Progressive Era. Thanks to their late nineteenth-century contributions to medicine, public health, and hygiene, bacteriologists had already claimed that they offered solutions to many urban problems. They now moved into the countryside, confident that bacteriology and applied botany could solve rural problems as well. Life scientists could claim that only they had the expertise to explain the importance of the microbial world in modern agriculture, and only they knew how to maximize and utilize soil bacteria's beneficial attributes. Bacteriologists were especially well situated—conceptually and institutionally—to see soil organisms as an untapped agricultural and economic resource. As historian Eric Kupferberg has put it, many experts came to see effective management of soil bacteria as the "apotheosis of scientific farming."[5]

Although one prominent historian has suggested that the "United States government took only a minor interest in this new field," much of the early work in soil bacteriology took place at the USDA.[6] This history fits well within a larger historiography of that institution, and with the historiography of Progressive Era science in general. Historians of science, especially the late Philip Pauly, have highlighted the aggressive efforts of USDA scientists at the turn of the century to harness the life sciences for the social good. As Pauly explained, government scientists believed that they could "rationalize and accelerate" progress.[7] Particularly under the leadership of Secretary of Agriculture James "Tama Jim" Wilson—the longest-serving Cabinet secretary in American history—USDA bureaucrats aimed to make the department a center of research in the life sciences. Determined to end the department's reputation as simply a source of free seed samples, patronage jobs, and answers to simple farming questions, Wilson wanted his scientists to wrestle with larger problems. Aided by the disproportionate power of rural legislators in Congress and their hopes

[4] Burrill (1904, p. 434).

[5] Kupferberg (2001, p. 163). See also Gossel (1988, pp. 1875–1900).

[6] Rossiter (1979, p. 235).

[7] See Pauly (2000, pp. 80–84); and Pauly (1994).

to address the populists' demands of the 1890s, Wilson managed to win lump-sum appropriations that funded specific scientific research projects—including several in the realm of soil bacteriology. Wilson also worked to turn the department into an institution that resembled a university in terms of its hiring practices, expectations for research, and control of the avenues of publication.[8] As one scholar has put it, the USDA under Wilson portrayed the "ideal bureaucrat" as one who was both a "researcher and a scholar."[9] He and his colleagues also expected USDA employees to be committed to political neutrality, scientific integrity, and delivering the lessons, practices, and vocabulary of modern science to the nation's farmers.[10]

The USDA aggressively expanded its agenda at the turn of the last century. A prominent example was the new team of "plant explorers," officially known as the Section for Seed and Plant Introduction (SPI). Formed in 1897, the plant explorers embarked on a mission to improve American agriculture, and society in general, through the systematic introduction of new agricultural crops. While it may be possible to criticize their efforts as a manifestation of botanical imperialism, or as a stepping stone in the rise of industrialized forms of agriculture, the plant explorers saw their work as a sincere effort to improve the standard of living for all.[11] According to one, Walter Swingle, the SPI crew hoped "to accomplish much good to the human race," either through the "pursuit of truth for its own sake or to benefit mankind."[12] Better known for their quest for tropical and other exotic plants that might thrive in the USA and its new territories, the plant explorers also found that both ordinary legumes and unseen bacteria offered additional weapons for their arsenal. The plant explorers soon moved into the new Bureau of Plant Industry (BPI), an agency formed in 1900 that linked several scientists united in the belief that coordinated work in bacteriology, botany, and other life sciences could improve crop production and address social concerns.[13]

Two men at the center of these efforts, Walter T. Swingle and George T. Moore, both born in 1871, were in many ways typical of the USDA's life scientists of this era. Swingle had entered Kansas State Agricultural College at the age of 16, where he became a protégé of the botanist William A. Kellerman and was a fellow student of his future USDA colleague, David Fairchild. Fairchild first joined the USDA in 1889, Swingle did so in 1891, and both became founding employees of the SPI in 1897.[14] Moore had earned a doctorate from Harvard, had ties to the scientific social circles at the Marine Biological Laboratory in Woods Hole, Massachusetts,

[8] Carpenter (2001, pp. 212–216). See also Hoing (1964); and Coppin (1990).

[9] Carpenter (2001, p. 216).

[10] For more scholarship on USDA scientists' efforts to address broader concerns, see Smith-Howard (2003), pp. 13–32); Hersey (2011); and Kimmelman (1983).

[11] For more on the plant explorers, see Pauly (2007, pp. 125–29); and Jones (2004).

[12] University of Miami, Department of Archives and Special Collections, Walter Tennyson Swingle (hereafter WTS) Papers, Box 30; WTS to Father, 17 December 1897.

[13] Pauly (2009, p. 84); and Stevenson (1954).

[14] Seifriz (1953); "Biographical Note" in finding aid to the Walter Tennyson Swingle Collection, University of Miami.

and before he reached the age of 30, he had become head of the botany department at Dartmouth College. Once they reached the nation's capital, both Swingle and Moore (as well as Fairchild and other USDA colleagues) joined Washington's influential Cosmos Club, becoming part of a community of scientists active beyond the halls of the USDA building.[15] As their stature and confidence in the Progressive Era ethos of improvement increased, they were more than ready to offer commentary on social issues beyond their areas of immediate expertise. Moore then gained national prominence when, with much fanfare, he announced that he had selflessly donated his patented methods for distributing bacterial cultures to the American people. Swingle, and especially Moore, seemed to represent prototypical USDA scientists, those whose work in the field and in the laboratory was destined to benefit the entire nation.

This history took a surprising turn in 1905 when Moore became the focal point of an apparent scandal. As described in more detail below, Moore's vigorous promotion of the only partially proven legume inoculants reflected poorly on the department's new scientific agenda and standards of professional ethics. When it appeared that Moore was trying to profit from his discovery, he was pressured to resign and quickly faded from the national scene. But the episode had other significance as well, for it pressured USDA scientists to recast their work in ways that addressed threats to the department's reputation for integrity and the expectation that it promoted scientific advances that had been validated as effective and worthwhile. In the end, the sudden rise and collapse of the USDA's soil bacteriology projects proved to be a reflection of both the prospects and the limitations of hopes for widespread social improvement through Progressive Era science.

The Context of the "Nitrogen Question"

Since the origins of human manipulation of the environment through agriculture, maintaining soil fertility has remained among farmers' foremost challenges. In his 1798 *Essay on Population,* Thomas Malthus argued that it would become impossible for agricultural workers to produce enough food to keep up with the growing population. Malthus saw hunger and disease as inevitable, but less even pessimistic scholars also understood that the problem of maintaining soil fertility was a limiting factor in social prosperity. By the mid-nineteenth century, scientists learned more of the nitrogen cycle, and artificial nitrogenous fertilizers seemed to help bend that constraint. Fertilizers quickly became almost essential for commercial agriculture, and much of the global economy depended upon farmers' ability to find and purchase new sources of nitrogen. The issue became especially pertinent in the late nineteenth century as depletion of the nitrate mines of Chile and the guano beds of the South Pacific seemed imminent, as monopoly interests emerged to dominate the commercial fertilizer industry, and as the perceived closing of the American frontier

[15] On the Cosmos Club, see Pauly (2009, pp. 53–54); Flack (1975).

signaled that virgin lands would not offer a "safety valve" for farmers who depleted their soils.[16]

Breakthrough discoveries came in 1886, when Hermann Hellriegel and his colleague Hermann Wilfarth solved the ancient riddle of legumes' ability to utilize atmospheric nitrogen. The German scientists proved that legumes simply would not grow in sterile soils lacking bacteria, regardless of the type or quantity of fertilizers applied. However, when they applied a soil extract taken from a field previously cultivated with legumes, they found that peas produced impressive amounts of nitrogenous matter, even in sterile and unfertilized soils. The German scientists concluded that the nutrients could have come through the symbiotic work of bacterial microbes that lived on the root nodules of healthy legumes and transferred fixed atmospheric nitrogen into nitrates that plants could absorb.[17]

This was not simply another nuance in the scientific understanding of crops and soils. In the words of one witness to Hellriegel's public announcement, his paper was a "sensation" and "bravos" greeted the scientist when he left the podium.[18] The news opened the possibility of boundless natural soil fertility, perhaps eliminating the need for frequent soil analyses and costly chemical fertilizers. Scientists soon suggested that "diseased" soils might be improved by the application of small amounts of the desired microscopic organisms, a form of inoculation similar to how humans can be protected from dangerous disease.[19] Friedrich Nobbe and his colleague Lorenz Hiltner led the search to capitalize legume inoculation in the early 1890s.[20] By 1896, Nobbe and Hiltner had entered into an agreement with an emerging giant in the German chemical industry, later known as Hoechst, to produce their bacterial cultures on a commercial scale under the trade name "Nitragin."[21] The following spring, in 1897, the rival chemical firm Bayer introduced its own inoculant, "Alinit," which reportedly could assimilate atmospheric nitrogen for both legumes and nonlegumes. If successful, this product would be even more revolutionary, for it could conceivably make all agricultural lands permanently fertile.[22] Dozens of German experiment station scientists and practicing farmers lined up to test these potential panaceas, while an American scientist predicted that "germ" and "vest

[16] Gorman (2013, pp. 68–69); Smil (2001, pp. 8–12).

[17] Summaries of Hellriegel and Wilfarth's work are in Hellriegel (1887) and Clark (1895). Hellriegel and Wilfarth (1888).

[18] Archives of the Rothamsted Experimental Station, Harpenden, England, John Henry Gilbert to John Bennett Lawes, 28 September 1886. Further praise of Hellriegel's research is in Springer (1892).

[19] In 1884, the British writer Maxwell Masters predicted that future farmers would be able to grow as much with a "pinch" of the appropriate "ferment-producing germs" as with a ton of other fertilizers. See Masters (1884), p. 17).

[20] Hartmann et al. (2008).

[21] Farbewerke vorm. Meister, Lucius,and Brüning (1898). Townsend (1897). See also Aikman (1896).

[22] Geheimes Staatsarchiv Preussischer Kulturbesitz (hereafter GSBK), Berlin, I. HA Rep. 87B, Ministerium für Landwirthschaft, Domänen u. Forsten, Nr. 13236, Henry W. Böttinger to Ministry, 2 June 1897.

pocket" fertilizers would become the wave of the future.[23] Although early results were disappointing, many popular press writers hailed the potential of this discovery; as one wrote, it "lowered the boundary between gods and men."[24]

Crookes, Nitragin, and the American Reaction

Hellriegel's discoveries and the German patents for legume inoculants soon attained even greater significance. One hundred years after Malthus had made similar predictions, the British chemist William Crookes drove the issue home in his September 1898 presidential address before the British Association for the Advancement of Science. There Crookes warned that the population of the world's "wheat-eating peoples" was growing faster than farmers' abilities to meet the demand. Crookes predicted "grave peril" for the "civilized nations" if scientists failed to find new sources of nitrogen to replace the amounts lost perennially through grain cultivation. While Crookes seemed less concerned about the fate of the "rice-eating peoples," he cautioned that "the great Caucasian race could cease to be foremost in the world and will be squeezed out of existence by races to whom wheaten bread is not the staff of life." Presenting a thorough and reasonable analysis of the global production of wheat and the predicted demand for nitrogenous fertilizers, Crookes concluded that the world's supply of free nitrogen could be exhausted by the year 1931.[25] While Crookes was actually an optimist, and assumed that scientists would find solutions to the "nitrogen question" in time, the immediate effect was to provoke a great deal of public anxiety.[26] As historians such as Corinna Treitel have shown, Crookes's warnings fit closely within the era's debates over "biopolitics," or the notion that a nation's biological and nutritional health was a reflection of its geopolitical power.[27]

Crookes was virtually silent on how legumes and legume inoculants might have an impact on this issue, but those in the USDA were not. Walter Swingle, the

[23] For German examples, see GSBK, I. HA Rep. 87B, Ministerium für Landwirthschaft, Domänen u. Forsten, Nr. 13236, "Anbau Versuche mit Leguminosenimpfung unter Anwendung der Knöllchen Bakterien,"; Proceedings of the Curatorium der Königliche Pflanzenphysiologischen Versuchsstation, 10 August 1895; and Proceedings of the Curatorium der Königliche Pflanzenphysiologischen Versuchsstation, 21 April 1894. See also Sächsisches Hauptstaatsarchiv, Dresden; Ministerium des Innern, Nr. 15678, Vol. III, Stutzer to Ministry, 31 January 1898, and Storck to Ministry, 25 October 1898. For an early American example, see Duggar (1897).

[24] Townsend, "Nitragin," p. 202. See also (Anonymous. 1905h) "Inoculation of the earth"; Johnson (1900). On disappointing results, see GSBK, I. HA Rep. 87B, Ministerium für Landwirthschaft, Domänen u. Forsten, Nr. 13236, Stutzer to Ministry, 31 January 1898, and Storck to Ministry, 25 October 1898.

[25] Crookes (1898). See also Brock (2008, pp. 375–87).

[26] On the response to Crookes's speech, see (1898a) "Nitrogen and wheat" and (1898b) "Answering an alarmist"; (Anonymous. 1898) "The world's supply of wheat"; Noyes (1898); Davis (1899): "Crookes vs. Atkinson, Dodge, et. al."

[27] See Treitel (2008); and Dickinson (2004). Although these scholars focus on Germany, parallels with the USA are made clear.

USDA plant explorer then stationed in France, quickly dismissed Crookes's warnings because nitrogen-fixing legumes could provide an answer. Spurred directly by Crookes's speech, Swingle soon scoured European seed catalogs, experimental farms, and laboratories in search of promising varieties of sweet clover, peas, and other legumes. By early 1899, his travels had taken him to Italy, Greece, Turkey, Algeria, and Tunis as well. The hunt turned up scores of new legume varieties, including several that "seem to be a quite different character from any nitrogen collectors we are now growing in the South."[28] Swingle also called for American agricultural experiment stations to ramp up research on nitrogen-fixing plants, giving them "a real problem to work with."[29]

Swingle was even more excited about the possibility of legume inoculation. He had already visited the laboratory of Nitragin's developer, Friedrich Nobbe, and in 1898 he enthusiastically reported the news from France that "Alinit is very hot stuff," especially because many claimed it might be proven to work on nonleguminous crops as well. Swingle recognized that, if true, the inoculant would "revolutionize the culture of cereals in the dry rich lands of the [American] West."[30] Swingle also aimed to track down samples of the soils that had been planted in promising legumes, for these were sure to contain "the right kind of bacteria" for further study.[31] Upon his return to the USA, Swingle and his colleagues continued their study of soil bacteriology and a possible biological solution to the nitrogen question. "No doubt about it," fellow plant explorer David Fairchild wrote to Swingle in 1900, "the earth bacteria are going to be recognized as the most important factors in agriculture."[32] Research budgets at the USDA for soil, botanic, and bacteriological investigations exploded and in 1901 Swingle took charge of the department's soil bacteria work as head of the BPI's new Division of Plant Physiology.[33]

In his new role, Swingle immediately tried to lure the Dartmouth bacteriologist George T. Moore to lead the project. But Moore—who had already gained some prominence for his research on the relationship between disease and algae in urban water supplies—found himself comfortable in academia, and he especially enjoyed his connections with the emerging summertime retreat of American biologists at Woods Hole, Massachusetts. He was reluctant to alter his budding career.[34] But

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[28] Swingle Papers, Box 15, WTS to DF, 18 Oct 1898. For his complete 1898–99 itinerary, see Swingle Papers, Box 33, 8 December 1903. In 1901, the USDA again dispatched plant explorers to North Africa, men who returned with another 105 leguminous species. Library of the Missouri Botanic Garden, St. Louis, George Thomas Moore Papers, (hereafter Moore Papers), Box 1, WTS to George T. Moore, (hereafter GTM), 21 May 1901.

[29] Swingle Papers, Box 15; WTS to David Fairchild (hereafter DF), 11 September 1898.

[30] Swingle Papers, Letterbook 2; WTS to O. F. Cook, 30 October 1898, and WTS to O. F. Cook, 22 November 1898.

[31] Swingle Papers, Box 15; WTS to O. F. Cook, 21 October 1898.

[32] DF to WTS, 20 November 1900, Box 33, Swingle Papers. Fairchild (1938, pp. 196–197).

[33] For instance, American agricultural experiment stations employed zero bacteriologists in 1900, but 18 just 5 years later. See True (1937, p. 137).

[34] Kleinman (2010) and (Anonymous. 1965) "George Thomas Moore." For more on the Woods Hole laboratories as the summer home of a vibrant community of the nation's leading biologists,

speaking the Progressive Era language of improvement, Swingle insisted that "the nitrogen problem is a *big one* and promises *great results* both from a scientific and from a humanitarian standpoint."[35] As additional enticements, Swingle promised that Moore could maintain his summer ties with Woods Hole, he boasted of the doubling of the USDA's budget for botanical work in just 1 year, and he implied that Moore could hire research assistants as needed. In short, Swingle argued, there is "no such fund or organization anywhere in *the entire world*" that resembled the USDA.[36] Moore finally accepted the job after deciding that he could become "enthusiastic" about research on nitrifying bacteria.[37]

Swingle laid down Moore's first task—to prepare an improved legume inoculant—even before Moore had signed his USDA contract. Swingle sent clover samples to Moore while still on the Dartmouth campus, and he also asked Fairchild to seize the seeds of some promising North African legumes before they came onto the market—before the USDA could be accused of stealing a commercial product. Meanwhile, Moore gathered microscopes, soil sterilizers, and other research apparatus at Woods Hole, and Swingle, Fairchild, and Moore rendezvoused in Massachusetts to work out laboratory methodologies.[38] As his own research intensified, Moore demanded that "No effort must be spared" to get his hands on viable specimens of the German legume inoculants like Nitragin.[39]

Moore's quest also became a priority for the BPI and USDA as a whole. Even as the research was in its early stages, Moore's supervisor, BPI head Beverly Galloway, announced that soil bacteriology, with its potential to increase the nation's store of fertile soils, was "particularly" important, and he urged his scientists to quickly develop methods to multiply the proper nitrifying organisms and to distribute beneficial bacteria to farmers cheaply and effectively.[40] Moore soon confidently announced that an answer to the nitrogen question lay at hand. As Moore explained, he and his colleagues had "perfected" methods of artificial inoculation that were far superior to the Germans'.[41] After a visit to Nobbe's and other European scientists' laboratories in late 1903, Moore was even more convinced of the superiority of his methodology. He applied for a patent in May 1903, and in March 1904, those rights officially came under the USDA's control.

see Pauly (1988).

[35] Moore Papers, Box 1, WTS to GTM, 6 March 1901. Emphasis in original.

[36] Moore Papers, Box 1, WTS to GTM, 6 March 1901. Emphasis in original. For more on the USDA building research facilities and staffing that resembled a university, see Carpenter (2001, pp. 221–226).

[37] Swingle Papers, Box 23, GTM to WTS, 11 March 1901.

[38] Moore Papers, Box 1, WTS to GTM, 29 March 1901; National Archives, RG54, E26W, Swingle Letterbook, WTS to GTM 4 May 1901; and WTS to DF, 16 July 1901; and Swingle papers, Box 24, GTM to WTS, 10 July 1901; and A.F. Woods to WTS, 14 August 1901.

[39] Swingle Papers, Box 24, GTM to WTS, 27 August 1901. Emphasis in original.

[40] Galloway (1902, p. 56).

[41] Moore (1903). Another report in the volume asserts that the government cultures were "at least five times as great as the nitrogen-gathering power of the ordinary forms found in nature." See Wilson (1903, p. 21).

At the same time, soil improvement was becoming a national project that involved much of rural America. Significantly, Moore framed his research interests in botany and soil bacteriology in ways that matched the USDA's mission to become a national center of research in the life sciences. In short, he asked ordinary farmers to do much of the field trial work and generate positive publicity for his discovery. The government's policy was to send envelopes of desiccated bacteria stored on cotton balls, with instructions to first mix a packet of chemicals (provided in the package) with rainwater, add the bacteria, stir and wait 24 h, add another provided chemical, moisten legume seeds in the solution, allow the seeds to dry, sow them as normal onto fields, and keep records of their results. Remarkably, over 3500 farmers and other amateur researchers (out of some 12,500 who received samples) reported their results to the USDA. In Moore's words, this was "one of the largest experiments of this nature ever undertaken by any country."[42]

These field experiments could not have been successful without widespread public interest in soil improvement. Newspaper headlines told of "Bacteria from Uncle Sam," delivered at no cost, and even the *New York Times* placed news of Moore's bacteria distributions on its front page.[43] In addition, a wide range of popular writers, many of whom were no experts in the life sciences, generated the enthusiasm necessary for soil bacteriology and legume inoculation to seem essential issues. In 1903, for instance, the American novelist Theodore Dreiser, then earning his living as a freelance journalist, penned a magazine article that argued the soil question was one of the most important of his era. Poor soils, he believed, led inevitably to malnourished, poorly clothed, and ill-housed farmers, people who were unable to adjust to the social demands of modern life.[44] The well-known journalist Ray Stannard Baker visited Nobbe's laboratory in rural Saxony and returned with a most glowing report of the cutting-edge research facilities, including large trees that had been growing in "water cultures" of fertilized solutions that contained no soil, for over 20 years. Baker enthusiastically described Nobbe's legume inoculation ideas as an answer to Crookes's warnings of a nitrogen famine, and he praised the USDA's emerging plans to bring bacterial cultures into areas "deficient in nodule-forming germs."[45] Again alluding to Crookes's warnings, other evangelists of soil bacteriology celebrated underground microbes as ones that could help cure disease, conquer world hunger, and save the European races from collapse. The most optimistic writers believed that scientists might soon find a way to have nitrogen-fixing bacteria grow on the roots of nonleguminous crops.[46] Another writer framed the issue in terms of economic efficiency; soil bacteria could reduce labor costs by eliminating

[42] Moore and Robinson (1905a, p. 31).

[43] (1903) "Bacteria from Uncle Sam"; ad in New York Times, 8 April 1904.

[44] Dreiser (1903).

[45] Baker (1903). Baker also observed a "suggestion of intelligence" in soil bacteria, for they knew enough to behave differently in relation to the amount of nitrogen in the soil.

[46] Johnson (1900); Wood (1903); Clarke-Nuttall (1902/1903).

the demand for imported fertilizers and perhaps obviate the necessity for tedious crop rotations.[47]

Meanwhile, Moore and his colleagues intensified their well-orchestrated campaign to promote legume inoculants. Far from fearing the infamous muckraking journalists of the Progressive Era, USDA officials knew how to plant stories and how to manipulate the press in order to publicize its agenda, bringing attention to the department's timely response to the nitrogen problem. Through David Fairchild, Moore's BPI colleague and soon one of Alexander Graham Bell's sons-in-law, Moore delivered a talk and magic lantern show before prominent guests in the Bell home. It proved so popular that the inventor asked for an encore lecture the following week. There, Gilbert Grosvenor, another of Bell's sons-in-law and head of the National Geographic Society, offered to arrange publicity for Moore's new methods through both *National Geographic* and *Century* magazines.[48] Moore agreed to the idea, provided his USDA photographs, and maintained editorial approval for such articles. These reports praised Moore in no uncertain terms. The *National Geographic* piece declared that rumors of the nitrogen famine were "greatly exaggerated" and reminded readers that Moore had "generously deeded [his patent] to the American people." The *Century* article was similarly bold, featured a large portrait of Moore, and concluded with the promise "there is no section of country which will not profit from Dr. Moore's discovery."[49] Other popular magazines and newspapers also touted the USDA scientist, consistently praising him as an altruist who willingly passed up the chance for commercial wealth in order to make it possible for farmers to finally tap into the atmospheric nitrogen that bathed their fields.[50]

The ambitious bacteriologists and botanists at the USDA's BPI fully believed in the importance of their work. In the words of BPI chief Beverly T. Galloway, "to be a scientist is to be a man of affairs," and he pushed this colleagues to pursue an aggressive form of science that had recognizable and utilitarian public benefits.[51] Moore, Swingle, Fairchild, and others followed this mantra, and clearly were willing to become evangelists for their discipline and on various social issues issue of the day.[52] USDA scientists also spoke of the how their work could improve society. Galloway, for instance, argued that "mankind as a whole is bettered, and the struggle

[47] Schneider (1903).

[48] Moore Papers, Alexander Graham Bell to GTM, 18 March 1904; and Gilbert H. Grosvenor to GTM, 25 May 1904.

[49] Gilbert Grosvenor (1904a), "Inoculating the ground"; Grosvenor (1904b), "Inoculating the ground," p. 839.

[50] (Anonymous. 1905h) "The inoculation of the earth."

[51] Galloway (1904, p. 13).

[52] David Fairchild had proposed that a new international language could arise to help coordinate research efforts in the sciences. Swingle Papers, Box 33, DF to WTS, 10 August 1901. Swingle became a proponent of an artificial language called pasigraphy, which was based upon a common and overlaying set of symbols, like Chinese, which he hoped could eventually become a "nearly perfect language" and facilitate international communication. Swingle (1905). He later wrote in favor of another technique to improve international scientific communication—the metric system. See Swingle (1909).

for life is made less a burden" through applications of the work of modern botanists, and he was particularly convinced that no other branch of science would bring more benefit to mankind than bacteriology.[53] George Moore was even more blunt when he urged that more "able-bodied men" become research botanists in order to combat the perception that botany was "somewhat of an effeminate calling."[54] In a commencement talk that focused on the USDA's accomplishments, he urged his audience to be "as proud of having the finest and most efficient Department of Agriculture in the world as he is of nation's possessing the biggest gunboat."[55] Moore situated his own legume inoculation work in the context of larger national concerns, because in effect legume inoculation expanded the nation's cultivated acreage. He also envisioned an expanding role for USDA research, for it could also lead to improvements in the industries that depended upon microorganisms, such as brewing, wine making, and cheese making. Interestingly, Moore gave these optimistic talks even as the foundation that he had built at the USDA was beginning to crumble.

George Moore and the National Nitro-Culture Company

The excitement over legume inoculants and a patent protecting the Moore method soon attracted entrepreneurs. In July 1904, two investors in the National Nitro-Culture Company (NN-CC) of West Chester, Pennsylvania, visited Moore at his Woods Hole summer retreat. They soon offered him a job at more than double his USDA salary, promising he would need to work only a few hours each day. Moore initially declined the offer, but unsurprisingly, he did hope to parlay it into a higher salary.[56] His supervisors promised to help, but it is telling that BPI chief Galloway framed the issue in ways that reflected the USDA's commitment to a broader agenda. In fact, Galloway had already delivered a major speech in which he stressed the importance of scientific integrity and the need for government scientists to ensure that "trust imposed on us has been fully and honestly respected."[57] There is a "certain prestige" that comes with government work, Galloway believed, and he warned Moore that joining a commercial enterprise would cause him to lose "at once [his] caste as a scientific man."[58] For a while, Moore resisted the temptation.

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[53] Galloway (1902, pp. 49–59).

[54] Moore (1905).

[55] Moore Papers, Box 1, GTM, "The creation and development of plant industries by the government," [undated commencement speech, c. 1904 or 1905].

[56] National Archives, RG 54, A. F. Woods Letterbooks, Book 2, A. F. Woods to GTM, 22 July 1904 and A. F. Woods to GTM, 29 July 1904.

[57] Galloway (1904, p. 12).

[58] National Archives, RG 54, E1, Box 38, [Beverly T. Galloway] to GTM, 2 August 1904. In any event, Moore's salary increased to US$ 3000 in early 1905, a 67 %increase over his salary when his employment began in late 1901. See National Archives, RG 54, A. F. Woods Letterbooks, Book 2, A. W. Woods to B. T. Galloway, 20 March 1905.

As Moore was deciding whether to stay at the USDA, he continued to push "nitro-cultures," as legume inoculants were becoming known, through his Washington connections. Two USDA publications that appeared in January 1905 were examples. Although these contained sensible caveats and presented a sober analysis of the facts, the louder message was summarized in one of the pamphlet's subtitles: "The Successful Use of Artificial Cultures by Practical Farmers."[59] An unpublished draft of one document included especially hyperbolic language: If the product could be developed for nonleguminous crops, it announced, "We will have something valuable almost beyond comprehension."[60] In any case, the published report asserted that Moore and his new inoculant had succeeded beyond all expectations.[61] The longer bulletin included about 150 favorable testimonials from farmers, not one that was unfavorable, and tellingly, no reports from professional botanists or experiment station scientists. The government's warnings, presented in a section entitled "when to expect failure with inoculation" were buried on page 29 of one pamphlet, and it brushed aside data indicating a failure rate of over 25 %.[62]

The publicity campaign of 1904 and Moore's publications of January 1905 exacerbated the storm of demand for the government's "nitro-cultures." Farmers flooded BPI offices with some 40,000 requests for free samples, up to 1000 per day.[63] Harvard's prominent botanist and Moore's former professor, William Farlow, begged Moore for a "'coke' of your leguminous 'tonic'" as a special favor.[64] The USDA struggled to find a way to deal with the thousands of correspondents—including diplomats and agricultural leaders from Canada, France, Germany, Russia, Australia, and Martinique—who were disappointed to learn that demand exceeded supply; soon only those who funneled their requests through influential Congressmen and Cabinet officers enjoyed much success. But this too was a problem, for it came into conflict with the department's commitment to focus on research and get out of the business of supplying samples through political patronage. BPI chief Galloway and Assistant Chief Albert Woods both feared that widespread demand for free bacterial samples cost excessive time and money, and also detracted from the bureau's broader mission. As Galloway put it, "I believe that the general and promiscuous distribution should be stopped" and replaced with a more "systematic" approach.[65]

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[59] Moore and Robinson (1905b); and Moore and Robinson (1905a).

[60] National Archives, RG 54, A. F. Woods Letterbooks, Book 1, Draft of Report "Nitrogen-Fixing Bacteria,"Book 1, [undated, but likely late 1904].

[61] Preface to Moore & Robinson (1900b), 5.

[62] Moore & Robinson (1900b), 45. The data in this report were based on a summary of 2502 replies received by 15 November 1904. The data in the second report were based on a summary of 3540 replies received by 31 December 1904. The failure rate had improved slightly, now only 21 %. As before, these testimonials conspicuously did not include a single comment from the hundreds of people who reported that the inoculant provided no benefit at all.

[63] National Archives, RG 54, A. F. Woods Letterbooks, Book 1, GTM to Assistant Secretary, 18 April 1905.

[64] Moore Papers, Box 1, W. G. Farlow to GTM, 29 January 1905.

[65] National Archives, RG 54, A. F. Woods Letterbooks, Book 1, A. F. Woods to GTM, 18 November 1904, and B. T. Galloway to A. F. Woods, 21 January 1905.

The government eventually ceased its free distributions, but that only increased the demand at the private firms. Meanwhile, the NN-CC had secured endorsements from experiment station scientists, such as George Washington Carver, by offering them the privilege to work as wholesalers in selling the commercial product to farmers and dealers.[66] Business at the NN-CC was booming, enough to make West Chester's postmaster complain of his suddenly increased workload.

Meanwhile, Moore was becoming something of a national hero. In September 1904, the *Washington Post* asserted that if there were more men like him in the government, there would be less graft.[67] His work on purifying drinking water also continued to keep him in the limelight, a useful example of how the agricultural sciences could also be helpful in solving urban problems.[68] In January 1905, an organization in Ventura, California, sent to Moore an unsolicited "resolution" that praised him for his "generosity…and patriotism in presenting the [inoculation] discovery to the American people."[69] In March 1905, *Scientific American* published back-to-back articles in the same issue on the two distinct areas of Moore's research.[70] That spring, Moore's alma mater, Wabash College, congratulated him on the "services rendered to the American people" and had him deliver a commencement address, just 11 years after he had walked the same campus as an undergraduate.[71]

Nevertheless, a few skeptics began to question the efficacy of legume inoculants in general and the Moore patent in particular. In many ways, the rural press proved to be more cautious and sensible about the legume inoculation hoopla than the mass market journals and USDA publications. *The Country Gentlemen,* for instance, published in 1904 a sober and thoroughly footnoted review of the scientific literature, concluding that artificial inoculation would be effective only under specific soil conditions and was "in no wise a 'cure-all'."[72] *Wallace's Farmer* also commented on the unwelcome trend of popular magazine writers trying to become the distributors of agricultural knowledge, and strongly urged Midwestern farmers to focus simply on planting legumes on a regular basis.[73] For his part, the eminent Cornell professor Liberty Hyde Bailey suggested that legume inoculation might have value, but he also warned of sensationalized reports in the press.[74]

[66] George Washington Carver Papers Microfilms, Tuskegee Institute, Tuskegee, Alabama, Reel 2, Edward H. Jacob to George Washington Carver, 18 December 1904. Jacob promised to "amply compensate" Carver for his promotional work.

[67] Washington Post, 28 September 1904.

[68] Washington Post, 6 January 1905.

[69] "Resolution No. 17," to GTM, Box 1, Moore Papers.

[70] (Anonymous. 1905c) "Bacterial soil inoculation for vegetables"; and (Anonymous. 1905a) "An important discovery in the purification of contaminated water."

[71] H. Z. McLaw to GTM, 10 May 1905, Box 1, Moore Papers; and Indianapolis News, 14 June 1905.

[72] (Anonymous. 1904) "Soil inoculation." Also (Anonymous. 1905g) "Soil inoculation: What it can and cannot accomplish."

[73] (Anonymous. 1905f) "Soil inoculation"; (Anonymous. 1905d) "Government bacteria."

[74] Bailey (1905).

The journal *National Farmer and Stockman* and its lead correspondent, Alva Agee, led the charge. In his initial analysis, published in January 1905, Agee admitted that legume inoculation seemed promising, although he cautioned that for countless farmers, the soil naturally contained enough bacteria to make artificial cultures redundant and a complete waste of money. At first, Agee complained only that reckless publicity over the potential of legume inoculation was causing "harm…to the department [of agriculture] and to the public."[75] The journalist also warned that hype about the simplicity of "vest-pocket fertilizers" would "warp" farmers' independence and tempt them to ignore the traditional skills necessary to successfully manage their own soils and crops.[76] Agee also questioned why the government seemed determined to enter a market that could better be left to the private sector. In addition, the journal published letters from subscribers who complained that Moore's USDA publication declined to print the negative reports about inoculants that they had sent in.

The matter reached a new level in April 1905, following the appearance of an article by freelance journalist Raymond Porter in *Pearson's Magazine*. Although Moore had personally vetted and approved the author's draft manuscript, Porter's essay was perhaps the most hyperbolic yet. Subtitled "The Wonderful New Discovery Enabling Farmers to Do Away with Nitrogen Fertilizers," the article once again presented Moore's process as a solution to Crookes's nitrogen question and as an improvement over Nobbe's method. The issue was "beyond dispute," Porter added, "for the United States Agricultural Department itself says so."[77] Porter asserted that bacterial fertilizers promised tenfold productivity increases, and also (although illogically) both increased profits for farmers and lowered prices for consumers. He excitedly asserted that inoculants could bring both farmers and the nation benefits that were "almost beyond comprehension."[78] "In the opinion of agricultural scientists," Porter concluded, "not in the history of the Department of Agriculture has there been a more promising development."[79]

This article impelled Agee to challenge what he called the USDA's "campaign of advertising that was unique in the history of scientific agriculture."[80] He first made two investigative trips to the NN-CC's offices in Pennsylvania, where he found suspicious packages sent from the USDA by 1-day mail, and that the company had neither a bacteriology laboratory nor a bacteriologist. There he learned that the firm's business model was a rather simple one: Following directions on the labels of the USDA's free packages, it multiplied the bacteria and then repackaged them for commercial sale. Agee's reporting also took him to Washington, where he called upon Secretary Wilson, the Assistant Secretary of Agriculture, Willet Hays, and Moore himself. Each had a reasonable explanation for the department's position, so

[75] Agee (1905b) "Farm facts and fancies."

[76] Agee (1905a) "Bacteria talk."

[77] Porter (1905, p. 398).

[78] Porter (1905).

[79] Porter (1905, p. 403).

[80] Agee (1905f). "The booming of nitro-culture."

Agee left these interviews with renewed faith in the honesty of the government's research. In April 1905, both in private correspondence and in his publications, Agee explicitly cleared Moore of any impropriety.[81]

Yet Agee soon returned to the story, ever more curious about how the USDA scientists could "indulge in such a queer departure from the standards of scientific men." The state experiment stations, he noted, were now in the uncomfortable position of cautiously questioning the unconfirmed claims that emanated from USDA headquarters in Washington. The whole matter, Agee believed, threatened to bring agricultural science "as a whole into disrepute."[82] Agee's editorials urged the USDA to "stop worshipping at the shrine of publicity" and return to the kind of work that earns real respectability.[83] Then on 15 July 1905, Agee and his publisher delivered their evidence to President Roosevelt.[84] Agee soon presented copies of a November 1904 document that clearly showed how the company promised the scientist 141 shares, and his wife 43 shares, of the company's total of 250 shares, in exchange for Moore's commitment to deliver the methods of his "secret process" as well as any subsequent improvements exclusively to the NN-CC. Valued at $ 100 per share, the deal would have made the Moores quite wealthy indeed.[85]

Moore soon confessed to the whole affair. He admitted that, indeed, he had been offered a lucrative post with the NN-CC, and that, while still awaiting a pay raise from the USDA, he had supplied the firm with the bacterial cultures it needed to begin operations, taught its employees how to multiply the cultures, and supplied the firm with suggestions on how the products might be marketed.[86] He also admitted that his vigorous promotion of inoculants—in speeches and as the lead author of the two USDA reports—led to the rapid exhaustion of government supplies and drove up prices on the commercial market. It also became clear that the NN-CC had transferred stock shares to the name of Moore's wife as a way to secure the scientist's connection with the firm in case the USDA salary increase did not materialize. Moore also confessed that he had covered this up when confronted in April, then testifying that "neither directly nor indirectly do I hold stock in any of these companies." Moore dutifully submitted a letter of resignation on the next day.[87] Secretary Wilson promptly accepted the resignation, something that evidently came as a surprise to Moore.

[81] Agee (1905f, p. 125). In a telegram sent to Assistant Secretary Hays (at the Cosmos Club), Agee assured Hays that he was "entirely confident of your doctor's integrity." National Archives, RG 16, E8, Box 29, Alva Agee to Willet Hays, 22 April 1905.

[82] Agee (1905c). "Farm facts and fancies."

[83] Agee (1905d) "Farm facts and fancies."

[84] National Archives, RG 54, E1, Box 38, T. D. Harman to Theodore Roosevelt, 15 July 1905.

[85] National Archives, RG 16, Microfilm 440, James Wilson to the President, 10 October 1905.

[86] National Archives, RG 54, A. F. Woods Letterbooks, Book 2, A. F. Woods to B. T. Galloway, 20 March 1905, pp. 156–159.

[87] National Archives, RG 16, Letterbooks of the Secretary of Agriculture, Book 105, James Wilson to B. F. Barnes, 18 and 28 July 1905. Many of the details are repeated in Agee (1905e) "Nitroculture discredited"; and (1905) "New department scandal."

The episode brought ignominy to a department determined to stake a claim as a leader in American science. “Another idol shattered!” cried one newspaper editorial; “we had thought that the real scientist was a man above the sordid things in life!”[88] Other newspaper headlines screamed “UGLY Charge Made against Government Employee,” and “Nitro-Culture Graft!”[89] A few other newspaper writers came to Moore’s defense, including the comment in the *Washington Post* that “probably no young scientist of the age has gained such a wide and enviable reputation as Dr. Moore.” His “manly qualities and integrity” were well known, and the *Post* reported that Moore had been embarrassed by all the attention he had received.[90] Another paper pointed out that he could have made millions of dollars from his discoveries, and with a personal story that was “absolutely quixotic,” it would be impossible for any jury to convict him.[91]

But the Moore episode was especially noticeable because it coincided with several other alleged scandals that rocked the USDA that summer. Secretary Wilson also faced accusations of leaking crop reports to favored investors, of lavish expenditures through the Weather Bureau, of offering his son privileged access to gold lands in Alaska, and of profiting through the printing of meat inspection labels.[92] Added together, these episodes challenged the USDA leaders’ long push to establish a reputation for integrity and for socially useful scientific research. Three days after Moore’s resignation, President Roosevelt called Secretary Wilson to his vacation home in Oyster Bay, New York. The press reported that Wilson’s resignation was imminent, although the Secretary explained to a concerned farmer that “my fighting blood is up” and “I certainly shall clean house.”[93] In the end, Justice Department officials concluded Moore’s actions did not amount to a criminal offense; as Attorney General William Moody put it, federal laws “do not cover all classes of wrongs.”[94] Several of Moore’s allies, including Harvard University President Charles Eliot, lobbied to have him reinstated.[95] But Secretary Wilson had no interest; he told President Roosevelt that Moore had repeatedly deceived him and had “violated…the basic principles of ethics which should prevail in a scientific corps as in the Department.”[96]

[88] Savannah Morning News, 29 July 1905.

[89] Sandusky [OH] Star-Journal, 28 July 1905; Galveston Daily News, 28 July 1905. In its editorials, The National Stockman and Farmer showed some sympathy for Moore’s temptation to capitalize on his work. It found greater fault with the overall “rottenness” of the USDA, especially its “policy” of seeking notoriety at the expense of scientific rigor. See (Anonymous. 1905e) “Secretary Wilson’s responsibility.”

[90] Washington Post, 6 August 1905.

[91] [Chicago] Inter Ocean, 31 July 1905.

[92] Washington Post, 6 August 1905.

[93] Iowa State University Special Collections, James Wilson Papers, Box 4, James Wilson to C. D. Boardman, 22 August 1905. See also (Anonymous. 1905b) “Another department scandal”; Hoing (1964, pp. 176–182).

[94] Alexandria Gazette and Virginia Advertiser, 2 August 1905; New York Times, 20 August 1905.

[95] National Archives, RG 54, E 1, Box 38, Charles W. Eliot to President Theodore Roosevelt, 7 October 1905.

[96] National Archives, RG 16, Microfilm 440, James Wilson to the President, 10 October 1905. There had been an earlier offer to reinstate Moore to the payroll, but that was soon rescinded. See

Government Policy after Moore

But the damage had been done, and USDA leaders mobilized to restore the department's reputation for scientific integrity.[97] Evidently concerned that he could be implicated for profiting from his research, Swingle instructed his father to process legal papers to be sure that his name had been removed from the ownership of a commercial date farm in southern California.[98] Meanwhile, assistant secretary of Agriculture Hays demanded sales information from the NN-CC, hoping to defuse allegations that the company had made "millions" of dollars though its association with Moore.[99] As that was underway, Hays urged farmers to not depend "too much" on commercial inoculants until more test results were in. BPI chief Galloway also worked to distance the USDA from the NN-CC on the grounds that the firm lacked a "sufficient scientific basis."[100] He soon added that other firms were no better, as virtually all of the inoculating material on the market was "practically worthless."[101] The Department also quickly abandoned Moore's method of shipping bacteria stored on cotton, and launched a new method that used hermetically sealed test tubes.[102] Moore's massive public experiment project also came to an end. USDA officials now made the case that they had completed all of the necessary trials, and that it now was time to allow the private sector take over the legume inoculation industry.[103]

The episode also gave the state agricultural experiment stations the chance to reassert their legitimacy. Scientists working on the land grant university campuses had felt overlooked in an era dominated by Secretary Wilson and the other imperious Washington bureaucrats who attempted to centralize research and control spending in the agricultural sciences. Tensions became sharper in 1905 and 1906, as battles over the Adams Act—which promised greater research budgets for state-lev-

National Archives, RG 54, E 1, Box 38, [Beverly T. Galloway] to GTM, 1 September 1905; [Beverly T. Galloway] to GTM, 8 September 1905.

[97] Moore evidently took a job with the NN-CC through 1906, but he managed to reestablish his academic credentials mainly through his connections at Woods Hole. See Marine Biological Laboratory (1907) and Marine Biological Laboratory (1909, p. 19). Moore joined the faculty at Washington University in 1909, and he served as director of the Missouri Botanical Garden from 1912 to 1953. See Kleinman (2010).

[98] Swingle Papers, Box 30, WTS to father, 4 August 1905. There was good reason for concern. Swingle had invested—and urged his friends and family to do so as well—in a date farm that was virtually across the street from a USDA date research facility, one that worked primarily on improving the specimens that Swingle himself had imported from the Mediterranean and where Swingle had been a research advisor.

[99] National Archives, RG 54, E28, Letterbook 55, W. M. Hays to E. Jacobs, 19 August 1905.

[100] National Archives, RG 54, E5, Letterbook 70, B. T. Galloway to A. F. Woods, 21 August 1905.

[101] National Archives, RG 54, E5, Letterbook 79, B. T. Galloway to Charles F. Curtiss, 7 February 1906. Similar examples include National Archives, RG 54, E5, Letterbook 85, B T Galloway to R. M. Winans, 30 March 1906.

[102] Kellerman and Robinson (1905).

[103] National Archives, RG 16, Microfilm No. 440, Reel 53, James Wilson to William F. Atkinson, 28 August 1905.

el experiment stations—were fought in Washington. When the bill passed, research dollars shifted to the state level, which to some extent diminished the spotlight that had shone upon USDA scientists.[104]

The inoculation problem also gave state experiment station scientists the chance to monitor the commercial market. Tellingly, many of these reports were written in a new key, in a dry style that lacked the color and enthusiasm of earlier articles in the popular magazines. C. G. Hopkins of the Illinois station, for instance, complained that the entire industry had been built on "erroneous and misleading" use of the work of experiment stations and the USDA, and he warned many of the claims regarding inoculation are "greatly exaggerated and overestimated."[105] The Pennsylvania Agricultural Experiment Station reported results that showed farmers gained only the slightest possible advantage by using artificial cultures.[106] A New York Agricultural Experiment Station study revealed that government nitro-cultures had a brief shelf life, were "exceedingly unreliable," and were in any case unnecessary for a large majority of farms. Several stations soon confirmed the New York findings: nitro-cultures prepared according to the Moore method were difficult for farmers to prepare and ineffective in the field. This led to the "inevitable" conclusion that artificial inoculation was generally "unremunerative and unwise."[107] A scientist at the Texas Agricultural and Mechanical College reported that "farmers are being victimized," both by "worthless" inoculants and by exaggerated claims that had them applying inoculants to fields where they were unnecessary.[108] German studies similarly revealed what they called "several cases of swindle" in the US market.[109]

Back in Washington, the USDA's position became noticeably less visible and less vocal. Oddly enough, the bacteriologist who replaced Moore, Karl F. Kellerman, was the son of Swingle's and Fairchild's mentor at Kansas State. But his approach to the legume inoculation was cautious, and his laboratory continually focused its efforts on basic soil bacteriology research and routine market regulation.[110] Tellingly, Kellerman's publications prominently explained "when inoculations fail" on the first page, and he bluntly discussed the futility of attempting to use inoculants on nonleguminous crops.[111] Also symptomatic of the new approach, the USDA now refused to release photographs of its bacterial research to the popular press.[112] The

[104] Rosenberg (1964).

[105] Hopkins quoted in Kupferberg (2001, p. 216).

[106] Butz (1905).

[107] Harding and Prucha (1905); Harding and Prucha (1906); Voorhees and Lipman (1907, p. 105); and Starnes (1905, p. 101).

[108] El Paso Herald, 21 February 1906.

[109] GSPK, I. HA Rep. 87B, Ministerium für Landwirthschaft, Domänen, und Forsten, Nr. 13238, Schneidewind to Ministry, 5 January 1907.

[110] National Archives, RG 54, E2, T. R. Robinson to Karl F. Kellerman, 16 September 1908.

[111] Kellerman and Robinson (1908); and Kellerman (1910).

[112] Moore Papers, Box 1, Waldemar Kaempffert to GTM, 8 July 1907. The journalist Kaempffert, hoping to write an article for *Cosmopolitan* or *Century* magazine, approached Moore for photographs of legume inoculants after he had been denied access to USDA photographs.

BPI gradually ended its distribution of bacteria samples, and by 1915, its official policy was simply to investigate commercial firms and publish the names of any manufacturer whose inoculants fell below an acceptable standard.[113]

The Wider Meanings of Soil Bacteriology

For many people, the rise and fall of Moore and the NN-CC did not diminish hopes that soil bacteria could lead to social improvement. Some authors read implications into the phenomenon that went far beyond the science of symbiosis in the legumes and bacteria, confident that this could also reveal fundamental interconnections in the entire organic world. Such ideas struck a chord in the early decades of the twentieth century, as scientific discoveries and social reform movements seemed interconnected. As recent scholarship on the emerging Country Life Movement suggests, reformers believed that farmers had particular abilities and responsibilities to maintain soil fertility.[114] Soil preservation became a moral issue, and reformers wanted farmers to gain access to valid information on how manipulations of the unseen soil microbes affected the larger world. That too had social implications, for improved respect for farmers' status and intelligence could stanch the flow of valued rural citizens from farms to cities. W. S. Harwood's 1906 text *The New Earth* boldly articulated similar views and defended the country's investments in agricultural science as "conspicuous evidence that there is something else in America besides greed and graft."[115] Explaining that the "Old Earth" was in a state of decay, with desolate, untidy homes, indebted farmers, "deadening isolation," and "deepening hate," Harwood promised that agricultural science could lead to a "New Earth" of prosperous, progressive, modern, well-kept homesteads, where families enjoyed books, music, and culture.[116] Harwood's book explicitly connected rural reforms with the soil inoculation industry: Advances in the farmers' ability to gain wealth from atmospheric nitrogen, he said, was the surest way to keep "advanced tillers" on the farm.[117]

Meanwhile, the new commercial legume inoculation firms—offering products with creative names like Nitrogerm, Soilvita, Nod-o-gen, Stimugerm, Farmogerm, and UneedR—often embraced a similar rhetoric. For instance, an Indiana company co-opted the anticorporate language of agrarian radicals and promised that

[113] Powell (1927, p. 10). See also National Archives, RG 54, E2, Box 81, W. J. Spillman, J. M. Westgate, and Karl F. Kellerman, "Report of the Committee upon Methods of Legume Inoculation," and several letters of Karl Kellerman, August 1914. As the quality of legume inoculants became more reliable, experiment stations in Wyoming, Michigan, Missouri, Oregon, and Wisconsin sold their own bottled bacteria and used the proceeds to fund further research. See Kupferberg (2001, p. 216); and Leonard (1932).

[114] Peters and Morgan (2004).

[115] Harwood (1906, p. 334).

[116] Harwood (1906, pp. 1–5).

[117] Harwood, (1906, pp. 26–27).

bacteria—which it labeled "little helpers"—enabled farmers to earn great wealth "without the interference of any trust, syndicate, or other combine."[118] A California firm explained that farmers had a responsibility to prepare "country homes" for the "busy little people," or the "little famil[ies]" of legume bacteria that do work necessary for the very "survival" of humankind.[119] The American firm that claimed to follow the Nobbe–Hiltner process of manufacturing Nitragin made an allusion to Moore—an "optimistic bacteriologist, who probably meant well"—but whose methods of bacterial distribution via cotton balls had failed. This company's advertisements accented another social dimension, promising "more pleasures, more comforts, more owners, and fewer tenants" through bottled bacteria.[120] Inoculation firms also touched upon some early examples of ecological thinking, promoting soil bacteria as "natural" alternatives to chemical fertilizers. Campaigns that championed farmers' role in preserving and maintaining the environment also included explicit and implicit attacks on agricultural chemical and fertilizer monopolies. The American Nitragin Company's promotional literature asked "Why should we not use Nature's way when it is more economical and easier than the ways provided by man?"[121]

Conclusion

By 1910 or so, the notion that legume inoculations were panaceas for soil and social problems had diminished. While field trials had demonstrated that many farms could benefit from artificial inoculation, most indicated that the expense and effort were unnecessary in fields that had been recently planted in legumes. The situation reached a symbolic turning point in 1911, when Moore's successor, Karl Kellerman, admitted that soil bacteriology research had stagnated. Indeed, as historian Margaret Rossiter has indicated, American soil bacteriologists had become frustrated with the low levels of institutional support for their work and turned to their European colleagues for help.[122] Confessing that recent research "sometimes gives us baffling results," Kellerman expressed little of the confidence that had been evident earlier in the century. The only hope for soil bacteriologists during this "critical period," he explained, was to return to the laboratories of European scientists.[123] Even George Moore reentered the debate, now 7 years removed from the episode that had forced his resignation. In a speech he delivered in 1912, Moore said he regretted the days when "no theory [was] too bizarre, no miracle too improbable, so long as we [fell]

[118] Smith (1913, pp. 14–15).

[119] (Anonymous. 1915) Country homes for busy little people.

[120] (Anonymous. 1912) "Old farms made new."

[121] Advertisement for "Nitragin" Company, Milwaukee, circa 1912, from the University of California at Santa Barbara, Special Collections.

[122] Rossiter (1979, pp. 235–36).

[123] National Archives, RG 54, E2, Box 81, K. F. Kellerman to William A. Taylor, 9 January 1911.

back upon the soil bacteria to account for it." Perhaps symptomatic of an end to the Progressive Era faith that experts had uncovered the many mysteries of the soil, Moore now said that scientists' arrogance of the past had to end. Another lesson he drew from that era was that there was no reason for "any particular glorification of the biologist"—perhaps including himself—for the unknowns of science would always outnumber the knowns.[124]

Looking back at the turn-of-the-twentieth-century discussions of the "nitrogen famine" and legume inoculations sheds light on a time when soil bacteria fit within the era's ethos of improvement. Reformers found reason to hope that soil bacteria could provide an almost miraculous and inexpensive source of valuable nitrogen, and thus an attractive alternative to farming systems based upon chemical inputs. Promoters also touted soil bacteria because of their social implications, for they seemed to be a tool that could help keep desirable rural citizens on the farm. These ideals also affected the aggressive life scientists at the USDA. Walter Swingle mobilized quickly when he had the chance to respond to the "nitrogen question," and George Moore's more intensive research work reflected the department's call for a confident and valuable form of public science. Moore's improprieties eventually embarrassed the department, although his superiors evidently tolerated them before the summer of 1905 because of the publicity that the legume inoculation program generated. Such attention was also valuable for the scientists themselves, who were eager to claim that applications of botany, bacteriology, and plant introductions could improve society. These multiple ambitions ran into hurdles, however. In the end, the invisible, unreliable, perishable, and often unnecessary microbes of the legume inoculants brought hopes of both soil improvement and social improvement, but they also very nearly shook the USDA's reputation for scientific integrity.

Debates over Crookes's "nitrogen question" came to a sudden halt when the Haber–Bosch process, developed between 1909 and 1914, made artificial fixation of atmospheric nitrogen possible. The Haber–Bosch process soon became reified and ubiquitous, fundamental to the ever-expanding agricultural production of almost all industrialized nations. The many legume inoculation firms that had emerged in the first decade of the twentieth century represented in some ways a last gasp of the small-scale nitrogen producers, and most soon disappeared. While some advocates still pushed for alternatives to chemical inputs—such as "green manures," or the deliberate expansion of legumes' place in crop rotations—such campaigns typically did not challenge a paradigm that for decades has been centered on just a few grain crops and annual inputs of millions of tons of artificial ammonia fertilizers.[125] Soil inoculants are still available, but the worldwide demand has remained steady for some time.[126] The USDA plant explorers who scoured the earth for plant

[124] Moore (1912).

[125] Cafer du Plessis (2009).

[126] Krimsky and Wrubel (1996). In recent years, only about 15 % of the soybean crop has been treated with traditional commercial inoculants. Meanwhile, efforts to apply genetic engineering to nitrogen fixation have also reached limitations: Fixating microbes consume energy (via carbohydrates) that decrease the amount available to produce crop yields.

introductions scored a success of another kind when soybeans emerged triumphant among the hundreds of legume varieties they had tested. By 1973, when US production of soybeans surpassed that of wheat, Crookes's warnings about famine among the wheat-eating peoples seemed ironic and antiquated.[127] But this history is not finished. Agricultural experts have improved legume inoculation technologies over the past several decades, driven largely by hopes to deliver leguminous proteins and natural nitrogenous fertilizers to the developing world.[128] Especially in the 1970s, researchers sought what one scholar calls the "holy grail" of the biological nitrogen fixation: the possibility of using genetic engineering techniques to developing nitrogen-fixing cereals.[129] Until that breakthrough occurs, however, most of the agricultural establishment will remain tied to manufactured nitrogen fertilizers. Indeed, in recent times the greater issue has not been shortages of nitrogen, but an overabundance of the nutrient in the form of agricultural runoff and other pollutants.[130]

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