"Atoms in Agriculture"

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ATOMS IN AGRICULTURE

On a sunny afternoon in July 1957, Seymour Shapiro of Brookhaven National Laboratory's Department of Biology took a few hours to survey the progress of some ongoing experiments in plant biology. It was a couple of miles from the department to the experimental field, a short drive down a narrow road and past the DANGER signs to the edge of a tall chain-link fence. With a Geiger counter in hand, Shapiro entered the field and began his tour. The initial rows of plants he encountered appeared to be growing vigorously, whether apple trees, holly bushes, corn, oats, tomatoes, blueberries, roses, or even the weeds that sprouted up among these many species. As Shapiro walked towards the center, however, the plants thinned out, grew smaller and more twisted. Some of the trees were already showing autumn colors, months too early. The corn was clearly stunted. Berry bushes produced lumpy, unappetizing fruit. Weeds, too, became scarce. When he reached the center of the field, marked by a nine-foot metal pole, Shapiro considered the patch of lifeless ground encircling it. Everything was proceeding as anticipated.

During most hours of the day, Shapiro could not have entered the field much less walked so near the pole, which usually held aloft a piece of highly radioactive cobalt-60 that scattered radiation across the field. At mid-afternoon, however, his Geiger counter remained fairly still. The cobalt had been lowered into a lead shield below ground, a daily procedure that allowed him and other researchers to access this "gamma field" for a few hours without being subject to lethal doses of radiation. The field was used for a number of in-house projects, as well as the biology department's cooperative "radiation mutations" program. Many participants in this latter program, which was managed by Shapiro in the mid-1950s, hoped that the long exposure to gamma rays emanating from the isotope would generate useful mutations in the fruits, flowers, and trees they had sent to be grown in the field. Having surveyed the field Shapiro would be able to give an update to some of his cooperating researchers – which included arborists at the Brooklyn Botanical Garden, fruit growers from New York State, and flower breeders in Connecticut, among others – on the progress of the plants they had left to his care.[1] (Figure 5.1)

Biologists at the Brookhaven National Laboratory (BNL) had carried out investigations into the use of radiation in plant breeding since 1948, studies that grew up alongside the laboratory's better-known research programs in nuclear physics.[2] Of these various endeavors, the gamma field was perhaps the most striking, but it was only one of a number of radiation-generating tools investigated as potential aids to plant breeding in the 1940s and 50s. Researchers at the laboratory had access to other technologies including for example a portable cobalt-60 irradiator that could be moved around the field and a system for exposing seeds to neutron radiation in the nuclear reactor. Although Brookhaven biologists primarily used these for basic research in genetics, cytology, and physiology, the technologies were also promoted as tools for plant breeders that could be used to accelerate the appearance of useful mutations.

The idea that various forms of radiation might be helpful to breeders had been around for at least two decades by the time the program at Brookhaven was up and running.[3] The exploration of x-ray radiation as an agricultural tool had occupied some researchers in the 1930s; however, very little in the way of improved plants – or even useful traits – had been produced through x-ray breeding by the early 1940s. In the United States, attention to x-rays and other

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[1] The condition of the field and its operation in 1957 are described in detail in Daniel Lang, "Our Far-Flung Correspondents: A Stroll in the Garden," *New Yorker*, 20 July 1957, 30-59.

[2] On the early history of BNL see Robert P. Crease, *Making Physics: A Biography of Brookhaven National Laboratory, 1946-1972* (Chicago: University of Chicago Press, 1999).

[3] The term "radiation" encompasses a range of physical phenomena. The researchers whose work I discuss in this chapter were primarily interested in two forms of radiation: gamma rays emitted by radioisotopes and neutron radiation (here typically produced within a nuclear reactor).

radiation as potential tools of plant breeding had all but disappeared.[4] It took the scientific and technological developments of World War II to reseed this barren landscape. The massive government-funded research and development program that had produced the atomic bomb in wartime had also produced several sites for atomic-energy-related research, not to mention interest in nuclear techniques among scientists in many disciplines. After the war, oversight of the continued use and development of atomic energy transferred from the military to a civilian Atomic Energy Commission (AEC), whose members soon found themselves responsible for managing a wide range of nuclear activities.[5] From the outset, the AEC sought to create a positive view of nuclear research among Americans. This could not be done by calling attention to the primary purpose of such research, which was to support national security especially through weapons stockpiling, as this only emphasized its inherent dangers. The commission instead aimed to counter fears of and objections to continued military nuclear development by funding non-military programs that promised payoffs such as cheaper energy and better medicine, and then advertising these through speeches, news reports, and other outreach.[6] As a result, the AEC and the politicians who backed it fostered an environment in which a research program linked to agricultural improvement such as that at BNL in 1948 could flourish in tandem with the on-site development of a nuclear reactor – not in spite of it, but because of it.

The AEC was largely responsible for the surge of interest in radiation breeding that occurred in the 1940s and 50s, both in the United States and later around the world. It subsidized

[4] As described in chapter 2.

[5] A detailed account of the AEC, including its formation and early activities, can be found in its official histories: Richard G. Hewlett and Oscar Edward Anderson, *The New World, 1939-1946* (University Park: Pennsylvania State University Press, 1962); Richard G. Hewlett and Francis Duncan, *Atomic Shield, 1947/1952* (University Park: Pennsylvania State University Press, 1969); Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission* (Berkeley: University of California Press, 1989).

[6] This is discussed in greater detail later in the chapter. For a short overview of AEC efforts to promote peaceful uses of atomic energy, see Paul S. Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (New York: Pantheon, 1985), ch. 24.

first a revival and then a rapid expansion in the use of various types of radiation in plant breeding as part of its efforts to demonstrate that atomic energy could be applied to unambiguously positive ends. Just as the production and distribution of radioisotopes, highly subsidized by the U.S. government and made possible through its expanding nuclear infrastructure, is well known to have fostered new areas of medical, biological, and ecological research in the postwar years, so too did the opportunity arise for breeders to take advantage of these as a "new" tool of agriculture.[7] In this, radioisotopes and the other nuclear technologies used in plant breeding after 1945 differed significantly from their predecessor mutation technologies, including x-ray radiation and colchicine. Interest in the application of radioisotopes and other nuclear technologies to breeding was driven less by aspirations shared within the mainstream of genetics and agricultural research and more by government hopes and interests. And it wasn't just that they offered a novel peacetime use for nuclear energy, though this was certainly important. Mutation breeding also promised to counterbalance specific worries of the atomic age, including concerns about the harmful effects of radiation on plants, on animals, and especially on humans. Even as awareness of the dangers of radiation exposure increased in the postwar years, debated among scientists and fretted over in public, plant breeders – and especially the AEC-funded biologists who aided them – could offer proof that not all radiation-induced mutation was bad. After all, that very process might be the key to improving important crops like oats, wheat, or

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[7] On the history of radioisotopes in postwar science and medicine and the role of the U.S. government (through the AEC) in promoting their use, see Angela N. H. Creager, *Life Atomic: A History of Radioisotopes in Science and Medicine* (Chicago: University of Chicago Press, 2013). See also Timothy Lenoir and Marguerite Hays, "The Manhattan Project for Biomedicine," in *Controlling Our Destinies*, ed. Phillip R. Sloan (South Bend: University of Notre Dame Press, 2000), 19-46. On radioisotopes in ecology, see Joel Bartholemew Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology* (New Brunswick: Rutgers University Press, 1992), ch. 6; Stephen Bocking, "Ecosystems, Ecologists, and the Atom: Environmental Research at Oak Ridge National Laboratory," *Journal of the History of Biology* 28, no. 1 (1995): 1-47; Stephen Bocking, *Ecologists and Environmental Politics: A History of Contemporary Ecology* (New Haven: Yale University Press, 1997), Part Two.

soybeans. Such work offered glimmers of hope for potential benefits of radiation exposure in the midst of an ever-expanding cloud of radiation fears.[8]

The growth of radiation-induced mutation breeding in the United States in the postwar years, as facilitated by the AEC, was initially spurred through the efforts of researchers associated with the national nuclear laboratories that had been established in the aftermath of the Manhattan Project.[9] Brookhaven National Laboratory was probably the most influential site for the development of techniques that utilized man-made radioisotopes and other nuclear technologies in agricultural improvement. The activities of the Brookhaven researchers, in both basic genetics research and the exploration of particular applications of this research, led to a revival of interest in breeding via induced mutation within the United States. Their work inspired researchers at other sites, including those at an agricultural experiment station associated with a different national nuclear laboratory – Oak Ridge National Laboratory in Tennessee. At Oak Ridge, induced-mutation research fostered hopes among Southern agriculturists that nuclear technologies indeed offered unprecedented opportunities for the improvement of important crops. The Brookhaven and Oak Ridge research programs in turn paved the way for national and international attention to induced-mutation breeding programs based on nuclear technologies as well as popular interest in uses of atomic energy in agriculture and horticulture.

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[8] On the history of concerns about radiation and fallout, see Spencer Weart, *Nuclear Fear: A History of Images* (Cambridge: Harvard University Press, 1988); Allan M. Winkler, *Life Under a Cloud: American Anxiety About the Atom* (Urbana: University of Illinois Press, 1999). A concise history of responses to known or perceived dangers from radiation is Samuel J. Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley: University of California Press). On radiation safety in the postwar period see also Barton C. Hacker, *Elements of Controversy: The Atomic Energy Commission and Radiation Safety in Nuclear Weapons Testing, 1947-1974* (Berkeley: University of California Press, 1994).

[9] On the history of the national laboratories, see Peter J. Westwick, *The National Labs: Science in an American System, 1947-1974* (Cambridge: Harvard University Press, 2003).

Biology, agriculture and nuclear science

Although one Brookhaven geneticist in particular, Willard Ralph Singleton, proved to be a considerable force behind the surge of interest in using radiation in breeding at that institution, he could hardly have asked for more an congenial institutional setting. In many ways the development at BNL of the cooperative radiation mutations program (of which the gamma field studies were a major component) reflected the origins, organization, and aims of the laboratory as a whole much as it did any individual investigator's interest in radiation-induced mutation and its potential applications. For one, this research program emerged in part from a need to conduct biological research linked to the laboratory's nuclear facilities, an agenda that studies of the mutagenic effects of radiations addressed quite directly. Second, because the laboratory was also meant to be a hub for nuclear research in the northeastern United States, administrators were keen to develop programs that would engage scientists at other institutions – including ones that invited outside researchers to have biological materials irradiated at the laboratory facilities. And perhaps most important, the potential pay-off of the induced-mutation research was widely believed to be improved varieties of plants and new tools for creating these, contributions of this peacetime laboratory to nuclear science that would be unambiguously positive for human welfare. The existence of radiation mutations program can hardly be understood apart from this institutional context. […]

[NOTE: *I've excerpted here a section on the transfer of authority for nuclear technologies from military to civilian control and the history of the national laboratories including especially Brookhaven.*]

In 1948, the BNL biology department hired W. Ralph Singleton, a geneticist and corn breeder from Connecticut, to occupy one of the department's senior-level research positions.

Singleton might have seemed like an unusual hire for a nuclear laboratory: 48 years old in 1948, he had worked at the Connecticut Agricultural Experiment Station for more than two decades. There he had pursued basic genetics, for example studying the causes of hybrid vigor with his colleague Donald Jones. He was also well known for his work in practical breeding, having developed many varieties of hybrid sweet corn for Connecticut growers during his tenure at the experiment station.[10] However unusual it might have been at the nuclear laboratory, this strong background in agriculture was precisely the reason that Singleton was an attractive candidate to those in charge of the Brookhaven biology department.[11] They hoped that someone familiar with the workings of agricultural experiment stations would be able to coordinate activities between these stations and the department, especially as technologies like radioisotope tracers were made available for distribution beyond the national laboratories.[12] Soon after his arrival at Brookhaven, Singleton began investigations into the genetic effects of radiation in maize, work that would in fact bring agricultural interests and needs – and other agricultural researchers – into the center of the biology department's activities. […]

Beginning in 1949, Singleton together with several of his Brookhaven colleagues began to develop a new tool for plant irradiation research. This was a large field in which the biologists could monitor the effects of chronic gamma irradiation on plants. The field (and its subsequent incarnations) came to be known as the "gamma field" or sometimes the "gamma garden." It comprised a piece of cleared agricultural land with a radioisotope of cobalt-60 at the center, which was encased in a stainless steel pipe and could be raised ten feet into the air. The premise of this construction was that the cobalt-60 would emit constant radiation, primarily gamma rays,

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[10] Walton Galinat, "In Memoriam: Willard Ralph Singleton, 1900-82," *Journal of Heredity* 74, no. 3 (1983): 197-8.

[11] Singleton to Hollaender, 22 January 1948, UVa-WRS, Box 5.

[12] Singleton to Shull, 22 January 1948, UVa-WRS, Box 5.

which would bombard the specimens planted in the field continuously over the entire growing season. Singleton and Sparrow [a fellow plant biologist], accompanied first by junior research staff and later by senior colleagues, planted experimental crops in concentric circles around the source. There they would be exposed to various amounts of radiation, depending on their distance from the center. Because the radiation emitted by the cobalt-60 – the "source" – presented a health hazard in addition to providing a novel research technology, the source and pipe had been erected atop a cylindrical lead shield. When a researcher wanted to enter the field, for example to inspect, remove, or water plants, the source could be lowered into the lead shield by means of a remote control outside the irradiated area.[13] (Figure 5.2)

In its first season, the gamma field was used to grow maize (for Singleton's research), tomato plants (on behalf of a researcher at the Connecticut Agricultural Experiment Station interested in the effects of radiation on crown-gall disease), and a handful of other experimental species.[14] The field also contained, at its center, the 16-curie cobalt-60 radiation source. This was a very radioactive object, potentially dangerous to anyone who worked near it. To put the radiation intensity in perspective: the plants closest to the source in the 1949 experiments, at two meters from the steel pipe, were receiving in one *hour* of their months-long exposure approximately 45 times the amount of radiation that the International Commission on Radiological Protection in 2007 recommended the average person receive at maximum in one *year*.[15] The intensity of gamma radiation dropped off quite sharply as it traveled away (and

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[13] There are many published descriptions of the gamma field. See, e.g., Seymour Shapiro, "The Brookhaven Radiations Mutation Program," in *A Conference on Radioisotopes in Agriculture* (East Lansing: AEC, 1956); W. Ralph Singleton, *Nuclear Radiation in Food and Agriculture* (Princeton: Van Nostrand, 1958), ch. 26.

[14] Singleton, "Progress Report," 15 June 1949, UVa-WRS, Box 6; Nims to Haworth, 2 December 1949, APS-BDO Reel 9, Folder 10.

[15] Based on my calculations, using the conversion tools available at: http://www.radprocalculator.com/ Gamma.aspx. Most recent ICRP radiation exposure recommendations are from A. D. Wrixon, "New ICRP Recommendations," *Journal of Radiological Protection* 28 (2008): 161-8.

spread outwards) from the source; as a result plants furthest from the source in 1949, at a distance of 64 meters, received just a tiny fraction of this radiation dose – about 0.039 percent of that experienced by plants at 2 meters.[16]

Singleton expected in 1949 to see genetic changes among the plants nearest the source but nothing among those farther away. In fact, the aim of his experiment, as he described it, was to "reveal the amount of constant gamma irradiation necessary to produce a genetic change."[17] Singleton also planned to place seeds and seedlings of corn and barley in specially designed trays that would closely encircle the source, and in doing so determine the dose of gamma radiation lethal to a germinating seed.[18] In effect, he was calibrating the gamma field as a research tool. He had virtually no information on what to expect from chronic irradiation – and precious little evidence that such irradiation would be at all interesting to genetics research. […]

The gamma field exemplified the way in which the expansion of nuclear physics, especially through the increased availability of radioisotopes, shaped the research agenda of the Brookhaven biologists and by extension the development of techniques for inducing mutation. Until the development of the gamma field, studies of radiation effects had for practical reasons focused primarily on acute irradiation, such as short exposures to radiation produced by an x-ray machine or a cyclotron. These were, by necessity of the amount of electrical energy required, of relatively short duration. Chronic exposure could have been achieved through the use of radium, a continuous emitter of gamma radiation, except that radium was prohibitively expensive. It had been used in small-scale studies on plant life, especially in the earlier decades of the twentieth century, but it was certainly not suitable for studies that were both large-scale and long-term.

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[16] Based on my calculations (see previous fn.).

[17] Singleton, "Progress Report," 15 June 1949, UVa-WRS, Box 6.

[18] Ibid.

This changed with the expansion of nuclear physics during and after World War II, in particular with the proliferation of technologies that produced, whether intentionally or as byproducts, radioactive elements. For example, in a cyclotron the acceleration of charged particles and their subsequent collision with a target material can be used to generate a radioisotope. Prior to the war, cyclotrons such as those developed by the physicist Ernest Lawrence at the University of California–Berkeley had been used in this capacity, especially to produce radioisotopes for use in biomedical research and medical therapy; this continued to be an application of the ever more powerful cyclotrons built after 1945.[19] Radioisotopes can also be created in a nuclear reactor, through exposure of a target material to a flow of neutrons generated by the fission reaction or by recovering these from the fission by-products of the reactor. In 1946, the U.S. government directed the conversion of the nuclear reactor at Oak Ridge, Tennessee from its original purpose – the production of plutonium for the atomic bomb – to the mass-production of radioisotopes for medicine and research.[20] The production of radioisotopes after the war, undertaken and heavily subsidized by the U.S. government through the AEC, influenced biological research across the United States and around the world.[21]

This influence was evident in the gamma field. In 1948, with artificial radioisotopes more readily available, previously impossible large-scale studies of chronic irradiation could now be undertaken. One could think of generating long-term exposures under field conditions as opposed to in laboratory spaces, and over much longer periods of time. Instead of an hour of

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[19] Angela N. H. Creager, "The Industrialization of Radioisotopes by the Atomic Energy Commission," in *The Science-Industry Nexus: History, Policy, Implications. Nobel Symposium 123*, ed. K. Grandin, et al. (Sagamore Beach, Mass.: Science History Publications/USA, 2004), 144.

[20] Ibid.: 142.

[21] See references in fn. 7 above. On the global distribution of radioisotopes, see Jean-Paul Gaudillière, "Normal Pathways: Controlling Isotopes and Building Biomedical Research in Postwar France," *Journal of the History of Biology* 39, no. 4 (2006): 737-764; María Jesús Santesmases, "Peace Propaganda and Biomedical Experimentation: Influential Uses of Radioisotopes in Endocrinology and Molecular Genetics in Spain (1947-1971)," *Journal of the History of Biology* 39, no. 4 (2006): 765-94.

intense radiation under an x-ray, a plant could be continuously exposed to gamma-ray radiation for the entire growing season, from May to October. Furthermore, because such studies had not previously been done, they promised a potential route to groundbreaking findings in what was by the late 1940s a well-tilled field of inquiry. Singleton and his colleagues, for example, could claim to be pioneering a new area of research into radiation effects on plants though such research had been pursued since the turn of the twentieth century.[22] They quickly expanded the experimental work carried out in the gamma field. Singleton was surprised in the 1949 season by an unusually high rate of mutation seen in the pollen of just one type of maize planted in the field. He designed an experiment for the 1950 season to determine whether this was due to the inherent high mutability of the type, a difference in mutation between male and female gametes (i.e., pollen versus ova), or whether this was in fact a unique effect of the chronic gamma irradiation. He also obtained a stock of maize known to have a very low mutation rate, in hopes of seeing whether this low rate could be increased. Finally, with his eye on a bigger prize, he decided to see whether a beneficial mutation be reliably induced, by investigating how often a particular gene of interest – in this case a "short gene" in corn that caused a dramatic reduction in plant height – could be made to appear.[23] […]

And the expansion did not stop there. In 1951, the Brookhaven researchers decided to both relocate the gamma field and increase the intensity of its radioactive source. The new field boasted a 200-curie source of cobalt-60 that had been produced at Oak Ridge National Laboratory.[24] As those who planned the transport and handling of this potentially lethal object reminded Brookhaven staff, "it will be impossible for all intents and purposes for anyone to work

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[22] Sparrow and Singleton, "The Use of Radiocobalt as a Source of Gamma Rays," 29.

[23] Singleton, "Progress Report," 23 June 1950, UVa-WRS, Box 6.

[24] Because cobalt-60 has a relatively short half-life of 5.3 years, material had been added to the original source in the 1950 season to compensate for interim decay.

in the direct beam [of the cobalt-60 source]. Even at ten feet, the weekly maximum permissible dose will be acquired in approximately thirty seconds."[25] This dramatic increase in radioactivity meant that plants seven meters from the source would now receive about the same amount of radiation that plants two meters from the old 16-curie source had received. This in turn meant a circumference of 44 meters along which plants would receive this dose of radiation, instead of just 12.5 meters – and the expansion of course held for every radiation dose.[26] The scope of experiments expanded in turn. […]

Radiation and cooperation

When he was first hired, Singleton had expressed skepticism about using highly energetic radiation, x-rays in particular, in his research program. In 1948, he maintained that x-rays only generated chromosomal changes, "translocations and inversions and deletions," and not the more sought-after changes in genes or "point mutations" as they were known.[27] But his research at Brookhaven evidently led him to reconsider – in fact, to do an about face, and a rather quick one. In his initial negotiations, he had assented to the incorporation of x-rays into his research but only alongside the use of ultraviolet, which he expected would be far more useful; however on arrival this plan was evidently abandoned as he began almost immediately to explore the use of gamma rays (which are electromagnetic radiation like ultraviolet and x-rays, yet the most energetic and most penetrating, and therefore potentially the most harmful of the three) as a means to induce genetic mutations.[28] As a result of his initial studies, which suggested that the

[25] Stangby to Balber, "Tentative Handling of the 200 curies of Cobalt 60," 29 March 1951, UT-AHS Box 5. Emphasis in original.

[26] Singleton, "Quarterly Progress Report," 2 October 1951, UVa-WRS, Box 6.

[27] Singleton to Nims, 12 March 1948, UVa-WRS, Box 5.

[28] Ibid.; Singleton to Nims, 22 March 1948, UVa-WRS, Box 5.

rate of mutation in maize was dramatically increased by their exposure to gamma rays, he came to believe not only that these rays would induce the desired genetic mutations but that they might in fact induce useful mutations, and perhaps even be turned into a tool for breeders.

This latter hope first took shape in the project for inducing a gene for shorter corn. Years earlier, at the Connecticut Agricultural Experiment Station, he had discovered a mutation in sweet corn that produced shorter-than-normal plants. These could be hybridized with traditional types to create plants about six-feet tall instead of the typical fourteen feet.[29] Singleton claimed that the short corn plants were more efficient to cultivate, needing less fertilizer than their larger relatives. The application of this discovery was limited, however, as incorporating the genetic trait into the many different lines of inbred corn then in cultivation would be, to use his words, "laborious and time consuming." If he were able to induce this mutation in many different lines in the gamma field, however, this would eliminate his having to breed out over many generations the gamut of other unwanted traits introduced in a typical hybridization.[30]

This project, which does not appear to have amounted to anything, was only the beginning of his exploration of induced-mutation breeding. Following the 1951 season, Singleton proposed that some of the gamma field be given over to studies of somatic mutations in fruit trees – a proposal that not only soon became a very visible aspect of the laboratory's outreach activities.[31] […] In December 1952, members of the biology department organized a small conference, inviting representatives from most of the agricultural experiment stations and agricultural colleges on the east coast, as well as from the USDA.[32] The conference resulted in a

[29] "Scientist Converts Tall Field Corn into Short for Easier Harvesting," *New York Times*, 27 August 1948, 1; BNL, "Annual Report, July 1, 1950," 76.

[30] Singleton, "Progress Report," 23 June 1950, UVa-WRS, Box 6.

[31] Singleton, "Progress Report," 28 December 1951, UVa-WRS, Box 6.

[32] See letters of invitation, e.g., Curtis to Deering, 19 November 1952, APS-BDO Reel 9, Folder 10.

new program, launched in the spring of 1953, that brought together the nuclear technologies of Brookhaven National Laboratory with the expertise of agriculturalists stationed elsewhere, in order to evaluate "the feasibility of producing useful mutations in plants by means of ionizing radiations" that would use both the gamma field and other irradiation facilities.[33]

The program, often referred to as the "radiation mutations program," focused initially on the production of somatic mutations in trees and shrubs, which could easily be propagated asexually, but expanded in subsequent years to involve seed and pollen irradiation as well. Collaborating researchers interested in the effects of chronic irradiation could choose to have plants placed in the gamma field by the Brookhaven staff, cultivated there for one or several seasons, and then removed and returned for continued observation and cultivation.[34] In other cases it made more sense to apply gamma rays under more controlled conditions, in which case the plants would be treated in a small greenhouse that had been converted into a cobalt-60 irradiation facility.[35] And the gamma rays emitted in the decay of the cobalt radioisotope were only one of many types of radiation available at the laboratory. Brookhaven biologists had access to a number of radiation-generating tools, ranging from x-ray tubes to electrostatic generators to the nuclear reactor itself, and these, too, were made available to collaborators. The "thermal neutron exposure facility" at the Brookhaven nuclear reactor was one of the most popular of these. The facility, also called the thermal column, was used to study the effects of neutron radiation – that is, radiation composed of free neutrons produced through nuclear fission. It enabled the biologists to subject whole plants, seeds, shoots, cuttings, or scions to neutron radiation as it was produced within the nuclear reactor without disrupting the reactor's

[33] BNL, "Annual Report, July 1, 1953," (Upton: AUI, 1953), 44.

[34] Shapiro, "Brookhaven Radiations Mutation Program," 143-4.

[35] Ibid., 145.

operation.[36] (Figure 5.3) In the mid-1950s very little was known about the effects of thermal neutron bombardment on plants, and the Brookhaven biologists used the thermal column to conduct a considerable amount of basic research. Those running the cooperative program also used the thermal column to irradiate seeds of some 60 species for more than 100 researchers across the United States between 1953 and mid-1956 – hoping, despite their comparative lack of information, that it might prove useful to breeders.[37] […]

The success of the Brookhaven staff in attracting collaborators proved to be a boon to administrators of the laboratory as whole. It suggested that the biology program was helping the laboratory meet its goal of being a center of cooperative work not only in its physical science programs but also in the life sciences. The 1954 annual report of the laboratory, which emphasized the expansion of collaborative research ("one of the original objectives in establishing Brookhaven National Laboratory"), included the gamma field as one of its four major cooperative facilities – alongside the cosmotron, the cyclotron, and the nuclear reactor.[38] Despite the obvious interest of the Brookhaven biologists (and indeed the Brookhaven administration, too) in supporting and promoting the radiation mutations program, and with it the use of nuclear technologies in plant breeding, the laboratory's annual reports emphasized that the Brookhaven researchers themselves were not conducting agricultural research nor perfecting seeds and plants for release to the market. They were conducing basic research in genetics, and merely facilitating the application of their findings elsewhere. "The final development of the seed for commercial application is left to the agricultural experimental stations and others," noted one Brookhaven annual report, a statement that followed directly on a discussion of

[36] BNL, "Annual Report, July 1, 1952," 88.

[37] Shapiro, "Brookhaven Radiations Mutation Program," 148.

[38] See foldout diagram in BNL, "Annual Report, July 1, 1954," (Upton: AUI, 1954), "Annual Report, July 1, 1954."

potential agricultural applications of the biological research program.[39] Cooperation evidently had its limits – Brookhaven National Laboratory was not an agricultural extension agency.

Mutation breeding and mutation politics

Even before the official mutations program was in place Singleton had promoted his work to the public in terms of its potential agricultural benefits.[40] In January 1952, the laboratory announced the production of a "17,000-fold" increase in the rate of mutation in corn, a claim based on Singleton's research. It was presented as an indication that "radiation-induced changes… offer the possibility of speeding up the creation of new varieties of valuable food plants," not least by making it unnecessary to search the world for useful genes to incorporate into older varieties.[41] Such claims seem unsurprising, knowing in hindsight how the mutation studies at Brookhaven developed from basic research in genetics and cytology into cooperative agricultural investigations. But looking ahead from 1948, when Singleton first arrived at the laboratory, they were certainly not given. As was evident in his initial negotiations, he had been hesitant to employ radiation haphazardly in his research.[42] In his evaluation of x-rays as largely destructive, Singleton had aligned with the perspective of the geneticist Lewis Stadler, who persisted in the 1940s in emphasizing that the primary effects of x-ray radiation treatment were not gene mutations but gross alterations of the chromosomes that would not be useful to breeders. To judge from the absence of a major research program in the United States that employed x-ray radiation as a breeding tool in the 1940s, this was a widely agreed upon consensus.[43]

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[39] Ibid.: xii, xiii.

[40] "New Knowledge Hot Corn," *Pathfinder*, 19 September 1951, collected in UVa-WRS, Box 23.

[41] "Atom Study Points to Food Plenty by Fast Development of New Plants," *New York Times*, 31 January 1952, 4.

[42] Singleton to Nims, 12 March 1948, UVa-WRS, Box 5.

[43] On Stadler's perspective on the value of induced mutations, see Harten, *Mutation Breeding*, 50-1.

As he transitioned to a new perspective on radiation-induced mutation, evidenced especially in his championing of the cooperative program at Brookhaven, Singleton began to publically dismiss Stadler's evaluation that the effects of radiation were entirely destructive and therefore of little value to the breeder.[44] "My views on the usefullness [sic] of radiation in plant breeding have undergone a considerable change during the last four or five years," he noted in 1953, referring of course to the time he had been on the Brookhaven staff. "I think that we have all been under the influence of Stadler in this country, and Stadler had a definite feeling that all radiation induced mutations are deleterious."[45] By 1953 Singleton felt certain that radiation, including x-rays, gamma rays, and neutron radiation, could be put to effective use by plant breeders. There were a number of reasons for his new certainty. […]

Singleton was especially influenced in his opinions by the ongoing research at Brookhaven. He was enthusiastic about the high rates of mutation he had found in maize grown in the gamma field. In 1953, he gained more confidence in induced-mutation breeding from a seemingly spectacular successes of his fellow Brookhaven researcher Calvin Konzak in inducing a useful mutation. Konzak appeared to have produced an oat variety resistant to various types of rust, a fungal pathogen notoriously damaging to oat crops, using the nuclear reactor. The process had been straightforward: he had exposed seeds of a rust-susceptible variety to neutrons in the thermal column at the Brookhaven reactor, then cultivated two generations, the second of which he inoculated with the rust as it grew. Plants that survived the spread of the fungus he assumed had inherited some resistance to it; from these he grew a third generation that similarly displayed resistance. In 1953, Konzak claimed this as a significant demonstration of the usefulness of

[44] e.g., Singleton, "Atomic Energy and Abundance," address delivered at the University of New Hampshire Chapter of Sigma Xi, 28 October 1954, UVa-WRS, Box 18.

[45] Singleton to Mangelsdorf, 19 October 1953, UVa-WRS, Box 6.

induced mutations, and others at the laboratory, including Singleton, agreed.[46] Then Singleton himself, in collaboration with a graduate student, found what he understood to be several somatic mutations among carnations grown in the gamma field. Most striking among these was a carnation of the White Sim variety (typically white) that produced wholly red flower. He subsequently offered this apparent somatic alteration as further evidence that cobalt-60 would be an important tool of plant breeders.[47] And it was not just Singleton and others at Brookhaven who were enthusiastic about the implications of such studies – interest in the application of induced mutation in breeding began to pick up at institutions across the country.[48]

Some geneticists took issue with the growing attention to induced mutation that the Brookhaven program had fostered. In 1953, Joseph O'Mara of the Iowa Agricultural Experiment Station expressed dismay to his fellow geneticist Ernie Sears at Missouri over the changing focus of the plant breeding program at his institution: "We are in a forest of radiation of oats because a couple of young geniuses – Konzak at Brookhaven and [Kenneth] Frey at Michigan… discovered rust resistance in some irradiated oats in some extremely uncritical experiments."[49] O'Mara was equally dismissive of the claims made by the Swedish researchers about the improved qualities they had produced in a range of crops.[50] Both Sears and O'Mara had worked with Stadler at Missouri in the study of genetic mutation and knew well that external factors could affect an experiment so as to suggest higher incidences of mutation than actually occurred. O'Mara clearly shared Stadler's skepticism that any aid to plant breeding could ever emerge from

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[46] Calvin Konzak, "Stem Rust Resistance in Oats Induced by Nuclear Radiation," *Agronomy Journal* 46, no. 12 (1954): 401-3.

[47] Alan Richter and W. Ralph Singleton, "The Effect of Chronic Gamma Radiation on the Production of Somatic Mutations in Carnations," *PNAS* 41, no. 5 (1955): 295-300.

[48] For example at the State College of Washington (later Washington State University), Iowa State University, North Carolina State University, and the University of Minnesota, among others.

[49] O'Mara to Sears, 16 September [1953], WHMC-Sears, folder 549.

[50] O'Mara to Sears, 22 June 1954, WHMC-Sears, folder 550

the induced-mutation radiation studies, and there is evidence to suggest that Sears felt similarly.[51] The private conversation between O'Mara and Sears about the renewed interest in induced-mutation studies continued over the next several years, especially as such research expanded at O'Mara's home institution at Ames, Iowa, and as national and international attention to mutation breeding increased. "All that he knows about neutrons 'I could write on one as it went by,'" despaired O'Mara of one new convert to radiation genetics.[52] Such opinions reflected an apparent divide between genetics researchers, a few of whom obviously did not consider the surge of induced-mutation research at Brookhaven and elsewhere in a favorable light.[53]

Still, for a time, interest and enthusiasm arising from other sources advanced the cause of induced-mutation work regardless of whatever was the prevailing opinion among geneticists and breeders. These derived in part from the willingness – imperative, even – of the AEC to provide support for biological research to encourage positive assessments of atomic development. Because physics-related research seemed inextricably intertwined with the production of weapons, biological and biomedical research were the key focal points for government claims to using atomic energy as a tool for social good. The distribution of radioisotopes abroad for use in research and medical therapy, for example, was intended to project a global image of the United States government as a benefactor of science and a leading developer of non-military applications of atomic energy.[54] The AEC and the institutions it sponsored advertised their funding of life sciences research programs in the United States, too, through speeches, news

[51] See, e.g., a much later discussion: Sears to O'Mara, 12 March 1962, WHMC-Sears, folder 551.

[52] O'Mara to Sears, 18 January 1954, WHMC-Sears, folder 550.

[53] This is also discussed in Victoria Leung, "Between Farming and Radioscience: A Study of Induced Mutation Breeding, c1920-1980" (Masters thesis, University of Cambridge, 2007).

[54] Creager, "Nuclear Energy in the Service of Biomedicine"; Krige, "Atoms for Peace."

reports, conferences, traveling exhibits, and more, in an effort to convince politicians and the general public of the better world the commission was working to achieve.[55]

The radiation mutations program at Brookhaven easily aided in this national political endeavor. As part of one outreach effort in the spring of 1954, Singleton was invited to participate in congressional hearings on the uses of atomic energy in agriculture. The hearings, conducted by the Subcommittee on Research and Development of the Joint Congressional Committee on Atomic Energy, followed on a similar set of hearings the previous year that had highlighted another commonly touted public good arising from nuclear science – the development of atomic energy for electrical power. Such hearings, which through their circulation in newspapers and other public reports drew attention to non-military uses of atomic energy, were to no small extent a part an ongoing publicity campaign. What better area (other than cheaper energy production and curing cancer, of course) in which to claim benefits arising from atomic research, and from government funding of the same, than in the production of higher quality, lower cost food? From the accounts given at the 1954 hearings, there appeared to be a vast array of atomic applications that could be incorporated into agricultural research and production in the near future for the benefit of all Americans. Over two days, the committee heard about the use of radioactive tracers in the study of plant biology, nutrient cycles, animal metabolism, and soil fertility; the sterilization of food through nuclear irradiation; the destruction of plant pathogens through irradiation; and the use of radiation in plant improvement.[56]

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[55] For an overview of AEC activities in this period, see Hewlett and Holl, *Atoms for Peace and War*. On publicity of peaceful uses of atomic energy more generally, see Weart, *Nuclear Fear*, ch. 8. See also Martin J. Medhurst, "Atoms for Peace and Nuclear Hegemony: The Rhetorical Structure of a Cold War Campaign," *Armed Forces & Society* 23, no. 4 (1997): 571-93; A. Constandina Titus, "Selling the Bomb: Public Relations Efforts by the Atomic Energy Commission During the 1950s and Early 1960s," *Government Publications Review* 16 (1989): 15-29.

[56] The Contribution of Atomic Energy to Agriculture: Hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, Congress of the United States, Eighty-third Congress, second session, 31 March and 1 April, 1954.

Singleton, who was the key spokesperson for this last topic, warmed to his task of showing how his genetics research would contribute to the greater social good. He predicted that "the science of radiation genetics will soon become one of the most important events in the history of agriculture."[57] By way of explanation, he discussed Konzak's work using neutron radiation to create rust resistant oats, a success achieved in one-and-a-half years and at "a very small cost" that "would have taken at least 10 years by conventional plant breeding methods, at considerable expense." He described a new breeding effort of his own, designed to produce a strain of corn resistant to leaf blight through induced mutation.[58] Singleton also described the basic research component of his work, which he presented as an effort to determine how most effectively to produce mutation, and of course he mentioned the cooperative program. In summing up this range of activities, Singleton emphasized that plant breeders were "on the verge of a new era" thanks to the increased production of radioisotopes and other forms of atomic radiation and to the research programs that put these to use.[59] In other words, direct benefits would accrue to Americans through this AEC-funded research.[60]

Singleton's 1954 testimony, which was covered in the national news, drew attention to another important component of the Brookhaven mutations program and the role it played for the AEC. One round of questions pursued a concern seemingly far removed from agricultural production: Representative Carl Hinshaw, the chairman of the subcommittee, asked Singleton to draw a comparison between the radiation levels he used and those resulting from the fallout of

[57] Statement of Ralph Singleton, The Contribution of Atomic Energy to Agriculture, Hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, Congress of the United States, Eighty-third Congress, second session, 31 March and 1 April, 1954, 43.

[58] Ibid.: 44-5.

[59] Ibid.: 55.

[60] AEC officials would also use the example of the Brookhaven plant breeding research to make exactly this point. See, e.g., Willard Libby, "The Economic Potential of Radioisotopes in Agriculture," in *A Conference on Radioactive Isotopes in Agriculture, 12-14 January 1956, East Lansing, Michigan* (Washington: AEC, 1956), 5-6.

the atomic bombs dropped on Japan in 1945. When Singleton noted that the radiation from the bomb would have been far less, Hinshaw took the opportunity to share with the rest of the room his knowledge of the genetic effects of atomic fallout. "I know there has been some concern that there might be fallout in Japan of enough to do some damage and I do not believe that that is possible," Hinshaw began. During the interview, Hinshaw noted twice, in rapid succession, that no "noticeable mutations" had been found as a result of the bombings, and that the chances of producing such a mutation was "apparently... quite small."[61] Clearly he did not want Singleton's claim to effective and efficient production of mutations to be read as damning evidence against the testing or use of atomic weapons.

That a presentation of the plant mutations research at Brookhaven would lead to a discussion of the effects of fallout from atomic bombs on human beings points to the degree to which the risks of radiation exposure were both in the public eye and an increasingly urgent political issue by the mid 1950s. Concerns about the potential dangers of atomic radiation first appeared in the late 1940s, and received attention in both scientific and political conversation and in popular culture.[62] […] It was not until 1954 that this growing awareness of the potential dangers of radiation exposure spilled over into a large-scale public debate. On March 1 of that year, just one month before the hearings on agriculture described above, the explosion of a hydrogen bomb in Bikini Atoll by the U.S. government produced a vast and unanticipated shower of atomic fallout. American servicemen were overexposed, as were residents of nearby atolls, and the crew of a Japanese fishing boat within the range of the falling ash fell intensely ill from radiation sickness.[63] The international incident drew attention to the hazards of atomic

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[61] Statement of Singleton, hearings on the Contribution of Atomic Energy to Agriculture, 52.

[62] Walker, *Permissible Dose*, 10-18.

[63] For a history of the test and the events that followed, see Hacker, *Elements of Controversy*, ch. 6.

testing, and the AEC made new efforts both to understand the nature of radiation hazards and to convince the American public – increasingly concerned for their own health and safety – that they were not being exposed to undue harm.[64] Many geneticists were outraged when the AEC commissioner Lewis Strauss issued a public statement on March 31 assuring Americans that the radiation produced by atomic testing could never be harmful to humans; the subsequent disagreement between the AEC and geneticists, and among geneticists themselves, over the exact nature of the hazard presented by radiation played out in the popular press as well as scientific journals in subsequent months and years.[65]

Singleton's testimony, taking place amidst the early stirrings of this controversy, featured at the lead of several news reports of the hearings on agriculture where it offered a decidedly different vision of radiation. As one reporter noted, the subcommittee had taken "time out from the H-bomb hubbub" to learn how atomic energy could be used to "improve food production." He highlighted Singleton's red carnation and the high rates of mutation produced in corn in the gamma field as evidence that scientists had figured out how to make better crops more quickly with the help of atomic energy.[66] A report appearing in *Newsday* carried a similar, if more sensational report: "Scientists… are using radioactivity to 'speed up' evolution in plant life and may be able to use the same progress [sic] to develop a 'superior type' of animal."[67] The message was clear: far from solely wreaking havoc on living things, as one might reasonably have interpreted from the events of the previous few months, atomic radiation could in fact improve

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[64] Walker, *Permissible Dose*, 18-28.

[65] Carolyn Kopp, "The Origins of the American Scientific Debate over Fallout Hazards," *Social Studies of Science* 9, no. 4 (1979): 403-22. See also, on the continued debate among scientists, John Beatty, "Weighing the Risks: Stalemate in the Classical/Balance Controversy," *Journal of the History of Biology* 20, no. 3 (1987): 289-319.

[66] Edward F. Ryan, "Benefits of Nuclear Fission in Agriculture Are Cited," *[Washington Post?]*, [1 or 2 April] 1954. From Singleton's clippings file; see UVa-WRS Box 23.

[67] "Radiation Used to 'Speed up' Evolution, Scientists Disclose," *Newsday*, 2 April 1954, 5S.

the quality of human life by contributing to the improvement of other species. This was surely gratifying to some AEC officials.

It seems clear that Singleton and his colleagues did not necessarily need the support of the genetics community to continue their investigations in radiation-induced mutation breeding. The political demand for work such as theirs was significant, and this demand kept the Brookhaven research program afloat in the mid-1950s in spite of criticism that might have arisen elsewhere. Not only did it serve as an example of the potential social good arising from AEC-sponsored research and especially the use of atomic energy, it also presented mutations as a positive outcome of radiation exposure at a moment when attention was increasingly drawn to its dangers.

The UT-AEC Agricultural Research Laboratory at Oak Ridge

Though Brookhaven was the center of atomic-related mutation breeding work in the United States, it was not the only national laboratory to support a program of agricultural cooperation in the 1950s and 60s. Beginning in 1949, a program linking agricultural and atomic research took shape near Oak Ridge National Laboratory (ORNL), as a joint venture between the AEC and the University of Tennessee Agricultural Experiment Station. While radiation-induced mutation breeding garnered national attention in the mid-1950s through the activities at Brookhaven, researchers at this joint facility began their own in-house cooperative research program in radiation breeding to complement other, ongoing studies of nuclear applications in agriculture. Here the use of radioisotopes in plant breeding was not a sideline cooperative activity but a key component of in-house research. Whereas at Brookhaven a firm line had been drawn in which staff biologists were not to work toward the development and release of improved varieties, this was the explicit goal of much of the work at Tennessee – as one would expect from an agricultural research station, even one sited on the grounds of ORNL.

ORNL differed in many respects from Brookhaven. Its origins lay not in postwar interest in nuclear science, but in the Manhattan Project itself. Oak Ridge, Tennessee, had been the site of what was known during the war as the Clinton Laboratories. These were the first facilities for large-scale production and separation of uranium and plutonium isotopes.[68] Oak Ridge had developed rapidly as a scientific and industrial site. The U.S. government had acquired the land, remote and undeveloped, in September 1942; the atomic pile (later called nuclear reactor) was in operation in a little over a year; by 1943 there were more than 40,000 people living in the so-called Secret City.[69] As the war drew to a close, the future of the facilities and the many thousand workers in Oak Ridge seemed unclear. Scientists at the Clinton Laboratories and at other sites associated with the Manhattan Project successfully lobbied to continue as the centers of nuclear research and technology development after the war had ended.[70] At the Clinton Laboratories, this meant investigation of and innovation in reactor design, the production and shipment of radioisotopes for use in laboratory research and medical therapy, and the initiation of new research programs in nuclear science.[71]

Another, slightly more unusual, responsibility fell to the laboratory in its early years. Its staff looked after a number of Hereford cattle, most of which had been exposed to the atomic blast at Alamogordo, New Mexico – the first-ever atomic bomb explosion – in July 1945. The cattle, which displayed obvious effects of their exposure including open sores where radioactive

[68] For an overview of research at Oak Ridge, see Leland Johnson and Daniel Schaffer, *Oak Ridge National Laboratory: The First Fifty Years* (Knoxville: University of Tennessee Press, 1994).

[69] Charles W. Johnson and Charles O. Jackson, *City Behind a Fence: Oak Ridge, Tennessee, 1942-1946* (Knoxville: University of Tennessee Press, 1981), 24-5.

[70] Westwick, *National Labs*, 31-42.

[71] Johnson and Schaffer, *Oak Ridge*, ch. 2.

dust had settled on their backs, had been purchased by the U.S. government after the test explosion. A subset of the herd was then sent to Oak Ridge so that Manhattan Project health scientists could closely observe the animals and the effects of direct exposure to atomic radiation.[72] By 1948, Oak Ridge administrators were looking for a new management regime for the herd. The chief of the office of research and medicine at the laboratory approached the University of Tennessee Agricultural Experiment Station to ask the assistance of station staff in the managing the cattle. An initial negotiation with the University of Tennessee led to an expanded proposal in which the station would not only partner with the AEC in caring for the herd, but would also develop an entirely new experiment station outpost at Oak Ridge. The joint program, for which a contract was signed on May 11, 1948, was to involve the application of radioisotopes in agricultural research and the study of radiation effects on agricultural production.[73] (Figure 5.4)

The agreement created a new outpost for agricultural science – the University of Tennessee-Atomic Energy Commission (UT-AEC) Agricultural Research Laboratory – within an established network of eight state agricultural experiment stations. The laboratory was located on the Oak Ridge Reservation, the site of the national laboratory, but like the other Tennessee experiment stations it was overseen by the university.[74] In other words, this was not a case of practically oriented agricultural and horticultural researchers being invited to collaborate with the so-called basic research team housed at the nuclear laboratory, as was the case at Brookhaven. At the UT-AEC facility, station researchers developed their own agricultural research projects, sometimes but not always with assistance from Oak Ridge National Laboratory staff. As a result,

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[72] *UT-AEC Agricultural Research Laboratory* (Oak Ridge: UT-AEC, 1966), 3.

[73] "UT-AEC Agricultural Research Program," in *UTAES, Sixty-Second Annual Report* (Knoxville: University of Tennessee, 1949), 157.

[74] "UT-AEC Research Program," *Tennessee Farm and Home Science*, April-June 1954, 3, 10 (cit. 3).

its programs tended to be carried out and described in much the same manner as other experiment station research. Station reports emphasized that Tennessee farmers would benefit as they did from all the activities of the agricultural stations: "As the atom chasers uncover new information on life processes other Station scientists apply the information to research in their respective fields. And as practical results are determined, county agricultural workers of the Agricultural Extension Service pass along improved practices to farm families…" The final added benefit – of perhaps more interest to the AEC than to Tennessee farmers – was that "these tools demonstrate that the atom can be friend rather than foe in our way of life."[75] […]

It was not until 1954 that the Agricultural Research Laboratory added plant investigations to its roster of activities. Thomas "Tim" Osborne was brought on that year as an associate plant breeder in the botany department, and he subsequently established a new line of inquiry in plant irradiation. Beginning in 1954 he oversaw research on the improvement of annual forage crops, including lespedezas, crimson clover, and vetches. His approaches for each of these included the same techniques: attempts at "ordinary breeding" through hybridization, exposure to gamma rays to produce mutations, and colchicine treatment to generate polyploidy. Osborne seems to have understood the latter two methods as ways to goad the more recalcitrant species into improvement. That fall, he irradiated 38,000 clover seeds with gamma rays in the hope of finding mutated varieties with traits that would enhance their value as forage plants. As a report detailing the work noted, "The apparent lack of genetic variability in crimson clover, giving little hope of improvement through ordinary breeding, was attacked with colchicine and radiation."[76]

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[75] "UT-AEC Research Program," 10.

[76] *TAES, Sixty-Seventh Annual Report* (Knoxville: University of Tennessee, 1954), 21-2.

The station constructed an irradiation facility the following year, which was used for the ongoing research on radiation effects, and also for a new cooperative irradiation program.[77] The station's animal irradiation field had already been used for work involving growing plants and other highly sensitive material. But it could not be used in administering high-intensity gamma rays – a capability needed to treat dormant seeds in particular – and so Osborne and his colleagues designed and built the new unit especially for this purpose. It consisted of two concrete-block buildings sixty-four feet apart: one contained a radioactive cobalt source housed in stainless steel and the other functioned as a control house. From the control house, a researcher could, by means of a hand crank, raise or lower the cobalt source in the opposite building from the bottom of a water-well in which it was kept for shielding. Small objects such as seeds were placed in a plastic cylinder that would be completely surrounded by the cobalt source when it was raised, thereby receiving the highest levels of gamma ray exposure; alternatively, experimental materials could be placed on a circular wooden platform that rotated around the outside of the source. The in-house research program that relied on these irradiation facilities involved studies of the genetic and physiological effects of radiation on plants as well as studies intended to determine the appropriate dose of radiation for various types of seed.[78]

These activities were described using a formula typical for agricultural station research more generally. Any research undertaken at the station, no matter how fundamental it seemed, would eventually inform agricultural practices and therefore benefit farmers. A case in point is Osborne's participation in a soybean investigation, one of the more extensively publicized plant irradiation studies associated with the UT-AEC laboratory. In the 1950s, the soybean cyst

[77] *Sixty-Eighth Annual Report of the TAES* (Knoxville: University of Tennessee, 1955), 71.

[78] T. S. Osborne and A. O. Lunden, "The Cooperative Plant and Seed Irradiation Program of the University of Tennessee," *International Journal of Applied Radiation and Isotopes* 10, no. 4 (1961): 198-209.

nematode was particularly destructive to Tennessee crops, prompting researchers at the state's agricultural experiment stations to respond with investigations into its prevention or eradication. Plant pathologists conducted research to better understand the life cycle of the pest, and breeders sought resistant varieties that might be developed into productive new lines. Following this trend in research activity, Osborne conducted an induced-mutation project in which he exposed soybean varieties to gamma rays from cobalt-60 in hopes of producing useful mutations. Such mutations were to include "resistance to the cyst nematode," in addition to earliness and enhanced seed retention. He declared that "any desirable attributes found will be bred into an improved variety… then released to Tennessee farmers."[79] By 1962, Osborne's radiation-based improvement work included, in addition to soybeans, large-scale plantings of irradiated cotton, fescue, and orchardgrass.[80] Osborne's colleagues also participated in the induced-mutation research, and similarly directed their attention to projects that would aid Tennessee farmers. […]

The radiation facilities at the UT-AEC Agricultural Research Laboratory were also used to treat seeds and plants for researchers at institutions across the South.[81] This outreach work had been initiated with the approval of the AEC's Advisory Committee for Biology and Medicine, and partly in response to a presentation that Singleton had given to Southern agriculturists on the potential benefits of radiation to breeding. It was obvious to the committee that the UT-AEC facilities offered a chance to involve many more Southern agricultural researchers in nuclear-related science.[82] The resulting program resembled that at Brookhaven: collaborators who

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[79] H.S. Reed and T. S. Osborne, "Soybean Research in Tennessee," *Soybean Digest* 19, no. 5 (1959): 18-9 (cit. 19).

[80] *Progress of Agricultural Research in Tennessee, 1961-1962*, 37.

[81] *TAES 1955 Annual Report*, 70-1.

[82] Minutes for the Meeting of the Advisory Committee for Biology and Medicine, Oak Ridge National Laboratories, Oak Ridge, Tennessee, 5-7 May 1955, DOE/NV Nuclear Testing Archive, Las Vegas, Nevada, available at: www.osti.gov/opennet, accession no. NV0411745; Shoup to Roth, 19 May 1955, DOE/NV Nuclear Testing Archive, Las Vegas, Nevada, available at: www.osti.gov/opennet, accession no. NV0706973.

participated in the program could use the radiation facilities *gratis*, if they agreed to collaborate with on-site researchers by sending in reports on their results; subsequent investigation of radiation effects would have to be the responsibility of the cooperating researcher.[83] Those who wished to have seeds or other plant material exposed to neutron radiation could arrange to have this done in the nuclear reactor at Oak Ridge, though they had to pay a fee for the service.[84] (Figure 5.5) By 1961 more than fifty researchers had participated in the cooperative program.

The UT-AEC staff gathered data – or attempted to – on the outcomes of these irradiations in order to compile a chart of the "relative sensitivities" of the various species and seeds to radiation exposure or, as it was also described, their "radioresistance."[85] This, too, was pitched as a project essential for transforming radiation into an effective and reliable tool for practical breeders. Based on the data produced by cooperators, as compiled and analyzed at the station, any breeder would know the intensity and duration of radiation a particular crop should receive in order to achieve the desired balance of genetic change and seed survival. In other words it would facilitate the uptake of induced-mutation breeding.[86] Yet this comparative research apparently did not interest cooperators, most of whom dragged their feet on returning the paperwork with their observations.[87]

Osborne was disappointed by what he later called "the mortality rate" of those "who dabble in radiation-breeding," a rate he estimated to be about 80 percent.[88] He attributed the dropout rate to the cooperators' unrealistic expectations of quick and easy results. "Only after

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[83] Minutes for the Meeting of the Advisory Committee for Biology and Medicine.

[84] Osborne and Lunden, "The Cooperative Plant and Seed Irradiation Program," 199.

[85] Ibid.: 208-9.

[86] "Planters Now Can Predict How Well Seeds Will Grow," *Kingsport News*, 1 December 1958, 2.

[87] Osborne and Lunden, "The Cooperative Plant and Seed Irradiation Program," 208.

[88] Thomas S. Osborne, "Regional and National Program on Use of Irradiation in Plant Breeding," in *Southeastern Seminar on Atomic Progress in Agriculture* (Clemson College, South Carolina, 1961), 41.

they were in it did they realize it was not an automatic, self-adjusting, mysterious, and glamorous system whereby new varieties would somehow spring suddenly into being, needing only to be named and released by the victorious breeder," he lamented. "They expected a sort of 'Instant Varieties' package – just add radiation and stir."[89] Regardless of whether this caricature was fair (and it is difficult to assess in the absence of records from the cooperative program), Osborne and other mutation-breeding advocates may have had mostly themselves to blame. Osborne was a vigorous promoter of the use of atomic energy in plant breeding, and in agriculture more generally. His articles in the experiment station's popular journal, *Tennessee Farm and Home Science*, provide a case in point. These pieces extolled the benefits to farmers of radiation improvement via induced mutation. Though the results would not be immediate, because new types created through induced mutation would have to be crossed back to standard varieties or otherwise developed by breeders for a number of years, he argued that they would no doubt result in valuable plants in time.[90] The use of radiation to produce translocations was similarly valuable in his estimation, a method that "appears promising for such crops as oats; cotton; and hybrids of ryegrass and fescue, sericea and annual lespedezas, and among the true clover" – in other words, it was promising for many of the species Osborne's Tennessee farm constituents would be most interested in.[91] And Tennessee farmers were not the only audience for this message. According to Osborne, the radioactive sources that had been made available to growers throughout the South, including those provided at the UT-AEC laboratory and others distributed

[89] Ibid.: 41-2.

[90] T. S. Osborne, "Radiation and Plant Breeding," *Tennessee Farm & Home Science*, Apr-Jun 195[?], 8.

[91] Ibid.

by ORNL, were "potential contributors to agricultural improvements for the benefit of millions of people in several states."[92]

The UT-AEC plant-breeding program, which continued into the 1960s, used methods and technologies similar to those innovated and applied at BNL – but its staff directed these towards immediate practical achievements even more stridently than did their Brookhaven colleagues. In this the UT-AEC researchers were influenced perhaps by the visibility already achieved by the Brookhaven cooperative program and their claims to some successes in mutation breeding by the early 1950s. They were likely also influenced by their particular institutional context, that is, from the establishment of the program as one part of network of agricultural experiment stations rather than a division within ORNL itself. As such, the mutation-breeding program was – like other experiment station research – carried out with an eye to the needs of Tennessee farmers, and with attention given to solving pressing local agricultural problems, and only through this furthering the development of the science of the "peaceful atom." Finally, they undoubtedly were also influenced by the momentum of "Atoms for Peace," an initiative promoted initially by the U.S. government to spur the development of non-military uses of atomic energy worldwide. As the next chapter details, "Atoms for Peace" was in full swing by the late 1950s as the UT-AEC cooperative program was getting underway. In other words, even if it were not the primary aim of breeders at the Tennessee Agricultural Experiment Station to call attention to the peaceful uses of atomic energy, they nonetheless participated in the AEC's program for promoting the development of – and benefits to – nuclear research, broadly conceived. In doing so, they not only highlighted the potential insight that would accrue from atomic-aided research, but also encouraged the acceptance of radiation as a bona-fide tool for the plant breeder.

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[92] T. S. Osborne, "Atomic Tools Help Plant Breeders," *Tennesee Farm & Home Science*, Apr-Jun 1956, 3, 9 (cit. 9).

Transitions

Perhaps the most striking aspect of the resurgence of interest in the use of induced mutations for crop improvement in the postwar years is that it did not arise from the revelation that radiation derived from man-made radioisotopes could be used to produce some effect on genes or chromosomes that had been long hoped for but consistently unattainable. To explain by way of a comparison: the initial use of x-rays and colchicine in plant breeding had followed on assumptions shared among many researchers that agriculturists in particular would benefit by the development of a tool that would produce specific genetic changes (i.e., induced mutation or chromosome duplication). When the technology for producing these changes appeared, researchers sought to test their assumptions or to prove them correct. Radioisotopes, however, were not new tools, nor were there well-established ideas about their potential usefulness to breeders when they were introduced into American agricultural research after the war. Changes caused by exposure to radium had been demonstrated to be quite similar to those resulting from x-rays, and radiation-induced changes had for the most part been deemed useful in genetics research but not in agricultural application.

It took the shared impulse of scientists and politicians to develop applications for new nuclear technologies, and the resources deployed to this end by the U.S. government through the AEC, to create a shift in these attitudes. The Brookhaven research program proved key to the transition. There researchers such as Singleton moved from a sometimes skeptical renewal of induced-mutation research, to the exploration of its use in plant improvement, to an all-out embrace of mutation breeding and promotion of the idea, first in the United States and then (as the next chapter describes) around the world. The establishment of mutation breeding programs such as that of the UT-AEC Agricultural Research Laboratory, and the participation of many breeders outside the station in their work, confirm that a more positive assessment of radiation-induced mutation had indeed been established, even as clear results – in the form of improved varieties – remained slow in coming.

This is not to say that it was all public relations activity. Just as researchers who worked with x-rays and later colchicine characterized their work as an effort to craft effective and efficient tools for engineering plants to better meet the demands of agricultural production, so too did many who worked with radiation in the atomic age see themselves as perfecting a new technique. They recognized that the resurgence of interest in using radiation in breeding was not primarily driven by new discoveries about its usefulness, but rather by the sharp rise in access to radioactive materials and nuclear technologies.[93] Far from undermining their collective agenda, this seemed to support the argument that it had only recently become possible to perfect radiation as a tool of the plant breeder. Only now were many potent forms of radiation treatment more widely available, and only now had a whole coterie of researchers (many with AEC funding) taken up the study of radiation-induced mutation. If radiation treatment in the 1950s still produced only random effects, there was no reason to believe this would always be the case. Better knowledge of the mutation process would take breeders closer to what the biologist Harold Smith of Brookhaven characterized as a communal goal: "We seek to control more effectively and to speed up appreciably the tailoring of useful plants and animals to meet our needs."[94] This ambition, and the rhetoric of more precisely manipulating plants, was a crucial aspect of the proliferation of induced-mutation breeding programs around the world after 1955.

[93] e.g., R. A. Silow, "The Potential Contribution of Atomic Energy to Development in Agriculture and Related Industries," *International Journal of Applied Radiation and Isotopes* 3 (1958): 257-80 (cit. 266).

[94] Harold Smith, "Radiation in the Production of Useful Mutations," *Botanical Review* 24, no. 1 (1958), 1-24 (cit. 3).

Figure 5.1. Two researchers (unidentified) stand at the center of the gamma field. One can assume that at the time this picture was taken, the cobalt-60 source had been lowered into the shielded vault buried beneath the flower beds pictured here. Papers of W. Ralph Singleton, Albert and Shirley Small Special Collections Library, University of Virginia.

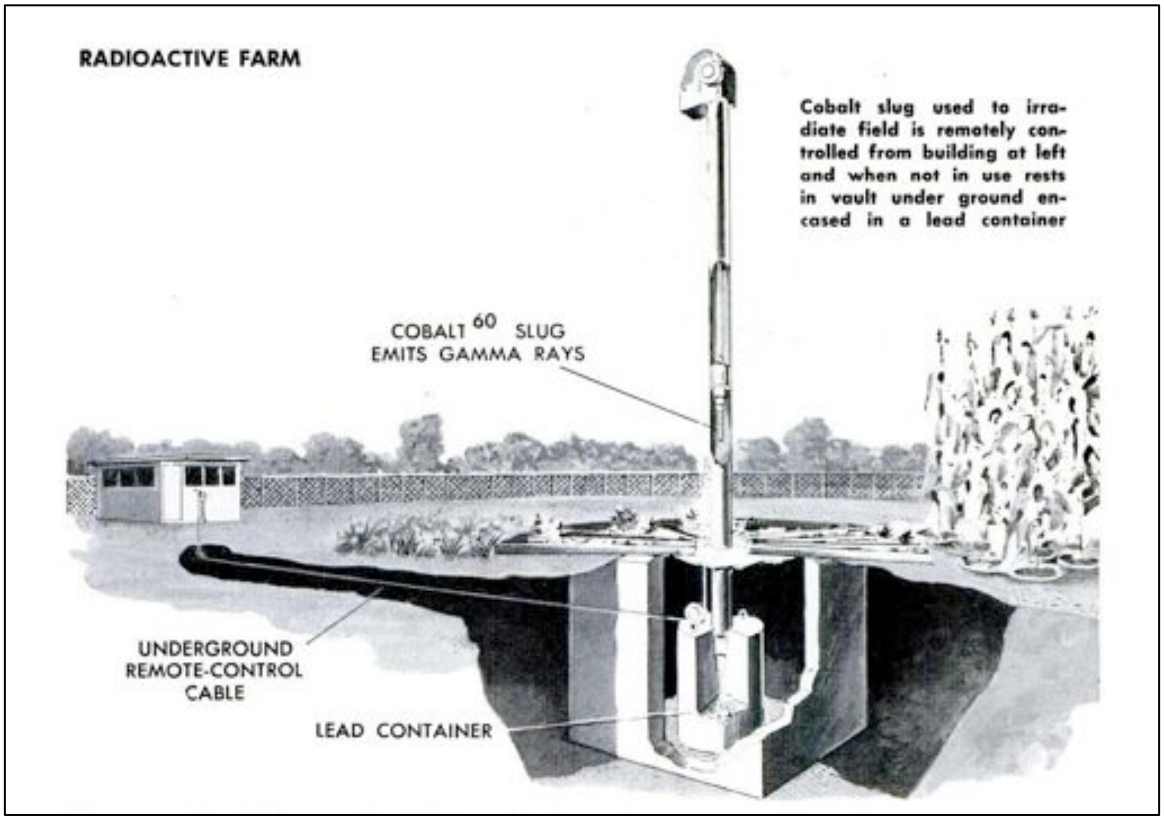

Figure 5.2. A diagram of the "radioactive farm" – the Brookhaven Gamma Field – indicates the mechanism by which the cobalt-60 could be raised and lowered. This version appeared as an illustration in *Popular Mechanics*, October 1958, 107.

Figure 5.3. A Brookhaven biologist places a lucite box containing seeds into the thermal exposure facility at the Brookhaven nuclear reactor. This "thermal column" enabled the biologists to expose materials to thermal neutron bombardment without interrupting the operation of the reactor. Papers of W. Ralph Singleton, Albert and Shirley Small Special Collections Library, University of Virginia.

Figure 5.4. "The time is not July 1945 and the setting is not New Mexico," read the caption on this image of cattle grazing in the glow of an atomic explosion, which was produced by the Agricultural Research Laboratory of the University of Tennessee and Atomic Energy Commission. As one among its many tasks, the laboratory was responsible for care of a herd of cattle that had been exposed to the first atomic bomb detonation and for conducting research on the effects of radiation on a range of agricultural organisms. The goal? To better prepare Americans for the aftermath of "a scene like this" which "could possibly occur at any point in the United States at any time." *UT-AEC Agricultural Research Laboratory* (Oak Ridge, Tennessee, 1966), 2.

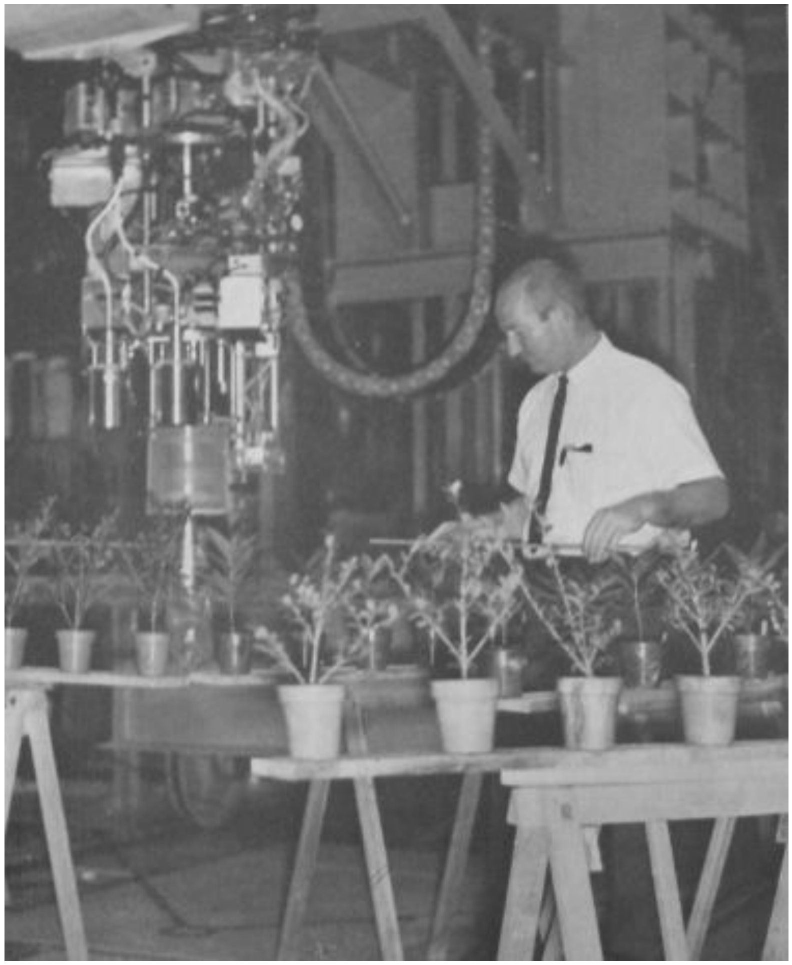

Figure 5.5. Neutron irradiation was conducted quite differently at the Oak Ridge reactor than at its Brookhaven counterpart. Here a biologist from the UT-AEC Agricultural Research Laboratory arranges plants at varying distances from the reactor to vary the amount of radiation received by each. *UT-AEC Agricultural Research Laboratory* (Oak Ridge, Tennessee, 1966), 36.