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Reshaping Technology in Wartime: The Effect of Military Goals on Entomological Research and Insect-Control Practices

JOHN H. PERKINS

The insecticidal properties of DDT, a chlorinated hydrocarbon insecticide,[1] were discovered by Paul Herman Mueller of the Swiss firm J. R. Geigy S.A. in 1939. The material was introduced into the United States in 1942 in the midst of World War II. The subsequent development and adoption of DDT substantially altered insect-control technologies and practicies.

The developmental work leading to DDT's adoption provides an interesting case study for examining major questions facing students of technology. What motivates the people doing research and development on potential new technologies? How do external social influences impinge upon scientists and affect the advances internal to the technology? The hope for economic gain has clearly been a major external factor, but it is not the only one. Aesthetic considerations and the world view of the inventor as formed by previous technologies have also been cited as significant external forces.[2] In this paper, I will argue that yet another factor, the desire to achieve victory in World War II, was paramount to American entomologists in developing DDT. The stimulus given to the rapid development of DDT by mili-

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[1] The formal chemical name of DDT is 1,1,1-trichloro-2,2-bis-(p-chlorophenyl)-ethane.

[2] Eugene S. Ferguson, "Toward a Discipline of the History of Technology," *Technology and Culture* 15 (1974): 13–30. Derek de Solla Price, "On the Historiographic Revolution in the History of Technology: Commentary on the Papers by Multhauf, Ferguson, and Layton," ibid., pp. 42–48. A major study of economic incentives to invention is Nathan Rosenberg, *Technology and American Economic Growth* (New York, 1972). Stuart S. Blume also argues convincingly for the necessity of studies on the external influences of society on the technical worker in *Toward a Political Sociology of Science* (New York, 1974).

tary conditions is similar to that observed for the development of computing devices, nuclear energy, and other inventions.[3]

* * *

The Geigy firm in Basel began in 1932 a search for moth poisons with a high affinity for wool. In 1935, the company broadened the potential commercial range of its research goals to include materials useful as seed disinfectants.[4] The following year, Mueller, one of the Geigy staff chemists, defined the biological properties of the object of his research as a synthetic contact insecticide.[5] Within a few years, Mueller had discovered that diphenyltrichloroethane showed substantial insecticidal activity against flies. Mueller proceeded to synthesize and test many derivatives of the compound, and he found in September 1939 that the substance p, p'-dichlorodiphenyltrichloroethane (DDT) had extraordinary contact-killing power, as well as long duration in the out-of-doors, where the compound was exposed to weathering. Mueller's research was guided by the criteria by which he was to recognize a desirable commercial product should he happen to synthesize it:

1. Great toxicity toward insects.
2. Rapid action, that is, onset of the paralysis within a few minutes.
3. Zero or weak toxicity toward warm-blooded animals, as well as toward fish and plants.

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[3] Thomas M. Smith, "Project Whirlwind: An Unorthodox Development Project," *Technology and Culture* 17 (1976): 447–64; and Richard G. Hewlett, "Beginnings of Development in Nuclear Technology," ibid., pp. 465–78. Although wartime conditions speeded the development of DDT insecticides and other inventions, war did not necessarily enhance overall insect-control technologies. E.g., effects of DDT on biological control, described later in this paper, indicate that DDT's impact on insect-control technologies involved a mixture of beneficial and detrimental features. Other authors, e.g., John U. Nef, have argued that in general war hinders scientific and technological progress at least as much as it stimulates it *(War and Human Progess* [Cambridge, Mass., 1950]).

[4] Andreas Buxtorf and M. Spindler, *Fifteen Years of Geigy Pest Control* (Basel, 1954). This book was originally published several years earlier under the title *10 Jahre Geigy Schadlings-bekampfung.* Although it is a company-sponsored, enthusiastic history, it contains a thorough review of the Geigy company's efforts to discover, test, manufacture, and market DDT insecticides.

[5] Insecticides are frequently classified as stomach or contact materials. The former must be ingested by the insect before poisoning occurs. The latter can kill merely by contacting the outside of the animal. An obvious advantage of contact poisons is that killing may be effected before the insect dines on the protected woolen textiles, while a stomach poison could begin to protect only after damage is done to the cloth. Some materials such as DDT possess both stomach- and contact-killing properties.

4. Absence of irritating action to warm-blooded animals, and little or no unpleasant smell.
5. Polyvalent action extending to the greatest possible number of insects.
6. Long duration of action, that is, great chemical stability.
7. Low price = economic advantage.[6]

Mueller used his criteria to compare DDT with some of its major competitors and concluded that, whereas DDT had only one defect, the other materials each had two or three problems (see table 1). The sole deviation of DDT from the "ideal" insecticide was that it does not have fast-killing powers. Hours often pass before the compound's lethal effects are detectable.[7]

TABLE 1

ADVANTAGES AND DEFECTS OF DDT AND ITS COMPETITORS*

Material	Meets Requirements	Does Not Meet Requirements
Nicotine	1, 2, 5, 7	3, 4, 6
Rotenone	1, 3, 4, 5	2, 6, 7
Pyrethrum	1, 2, 3, 4, 5	6, 7
Thiocyanates	1, 2, 5, 7	3, 4, 6
Phenothiazines	1, 3, 4, 7	2, 5, 6
DDT	1, 3, 4, 5, 6, 7	2

*Numbers refer to criteria 1–7 listed on pp. 170–71.

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[6] Paul Herman Mueller, *Histoire du DDT* (Alençon, 1948). I thank Christine Newman for translating the article. Mueller noted that Othmar Zeidler, an Austrian chemistry student, had reported the synthesis of DDT in 1873–74. Zeidler's work, however, was strictly a test for a synthetic procedure, without investigation of the usefulness of the product. Mueller did not cite any other reports of DDT's synthesis between Zeidler's work and his own. Zeidler's work on DDT consists of his dissertation, "Kenntnis der Verbindungen zwischen Aldehyden und aromatischen Kohlenwasserstoffen" (1873), and a published paper, "Verbindungen von Chloral mit Brom- und Chlorbenzol," *Berichte der deutschen chemischen Gesellschaft* 7, no. 13 (September 15, 1874): 1180–81.

[7] Mueller. In insecticidal preparations, DDT's inability to kill quickly is frequently overcome by mixing the compound with pyrethrum or other materials with a fast kill rate. Research subsequent to Mueller's work indicates that DDT meets criterion 3 (low toxicity toward warm-blooded animals, fish, and plants) only with severe qualification. The compound has low acute toxicity to mammals but is a chronic poison that induces tumors. The compound's high stability has led to its accumulation in the environment and thus its threat to populations of fish, birds, and perhaps man (Emil M. Mrak et al.,

World War II isolated Switzerland, and the Swiss became dependent upon their abilities to raise their own food. Swiss farmers, in efforts to increase their yields, began to use DDT, in Geigy's trademarked product Gesarol, against the Colorado potato beetle in 1941. At the same time that food supplies became critical, refugees from the war zone came into Switzerland infested with lice. The potential for typhus epidemics was thus high. The Geigy company began work in 1941 to test the possible effectiveness of DDT against human lice.[8] By September 1942, they had placed a ton of Neocid power (a trademarked product containing DDT and intended for control of human lice) at the disposal of the Swiss army commander, for the control of lice on refugees.[9] Thus, within three years of its initial discovery by Mueller, DDT was recognized in Switzerland as an effective synthetic organic insecticide for use in both agriculture and public health. Furthermore, Geigy was producing the material in Switzerland in substantial amounts.

The Geigy company began to inform its foreign subsidiaries and associates, as well as foreign governments, about DDTwithin two years of its initial discovery. In September of 1941, the company informed its U.S. subsidiary of a "new insecticide" that in the form of a 1 percent dust was effective against the Colorado potato beetle. The initial reaction of the U.S. company to this nonspecific information was unenthusiastic because of the success of lead arsenate in controlling the potato pest in the United States.[10] In 1942, the Geigy company informed diplomatic representatives of the belligerent powers in Bern about DDT and sent samples of the material to Geigy representatives outside Switzerland with instructions to approach the governments of the countries in which they were located.[11] In the fall of 1942, U.S. Geigy officials presented samples of DDT to Ruric Creegan Roark of the USDA.[12] Roark and his staff accepted the material, tested it, and

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Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health [Washington, D.C., 1969], pp. 7–19). The compound is sufficiently toxic to cucurbit plants like squash and cucumbers that it never has been useful on them.

[8] Mueller.

[9] H. Mooser, *Schweizerische medizinische Wochenschrift* 74 (1944): 947, quoted in T. F. West and G. A. Campbell, *DDT* (London, 1950), pp. 3–4.

[10] Victor Froechlicher, "DDT," *Soap* 20 (1944): 115, quoted in West and Campbell, p. 6.

[11] Buxtorf and Spindler (n. 4 above). There is some ambiguity about what type of information was given to the Germans. Mueller implies that the information was delivered only to the United States and the United Kingdom, but Buxtorf and Spindler imply that the information was also given to the Germans. The latter authors display a picture of a patent from the Deutsches Reich along with patents from France, the United States, Switzerland, and the United Kingdom.

[12] Froehlicher.

became enthusiastic over its potential. The grounds for their enthusiasm lay in the political background to the development of USDA's wartime research effort, to which we now turn.

* * *

The orientation of USDA research toward military goals had begun as early as 1940, when Secretary of Agriculture Henry Wallace directed the chiefs of the bureaus "to consider their possible contributions to national needs as the defense program approaches the stage of 'maximum effort.' " At that time, Wallace felt that it was not possible to describe precisely the situation facing the United States but that it was possible the United States would lose markets in Europe and Asia and that we might be cut off from our "normal" supply of strategic materials from the Far East. Wallace specifically wanted the bureau chiefs to describe the problems they would face and how those problems would be solved.[13]

Lee A. Strong, chief of the Bureau of Entomology and Plant Quarantine (BEPQ), asked a committee of BEPQ entomologists to prepare a defense-oriented program of entomological research. Strong also outlined, in a memorandum to Wallace, a preliminary list of entomological problems during wartime: insects in stored grains, wool, hides, and wood; termites; and sanitation problems, especially from flies. Strong emphasized the necessity for more research on the methods of combating insects.[14]

The initiation of open hostilities in December 1941 caused BEPQ to complete the transformation from a peacetime organization to one totally committed to war. On December 11, Secretary of Agriculture Claude Wickard ordered a complete review of all activities of all the bureaus of the department: "In the last year we have made considerable progress in shifting our work to defense activities. . . . Every activity now must be measured by the contribution it can make to a victorious conclusion of the war."[15]

Percy Nichol Annand, who became chief of BEPQ in the latter part of 1941, emphasized in a note to Wickard the great importance to the defense effort of certain insect-control programs conducted by the

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[13] Henry A. Wallace to Chiefs of Bureaus and Offices, August 23, 1940, file: USDA National Defense; series: Correspondence and Reports; subgroup: History of Defense and War Activities, 1941–50, Records of the Bureau of Entomology and Plant Quarantine, Record Group 7, National Archives Building. (Hereinafter records from this group located in the National Archives will be cited as RG7NA.)

[14] Lee A. Strong to Henry A. Wallace, September 19, 1940, ibid.

[15] Claude R. Wickard to Chiefs of Bureaus and Heads of Offices, December 11, 1941, ibid.

bureau. The Division of Insects Affecting Man and Animals (DIAMA) was giving technical advice and conducting surveys of mosquitoes with the U.S. Public Health Service, the army, and the navy. The DIAMA also was conducting programs of dog fly control in western Florida, training army sanitation personnel, and developing insect repellents. Annand pointed out that the bureau could assume more work in the research and development of insecticides.[16] The DIAMA, together with the Division of Insecticide Investigations (DII) headed by Ruric Roark, was to play the major role of introducing DDT to the United States.[17]

Although federal scientists were most immediately affected by the war, it is important to note that the desire to achieve victory was not limited to them. The entire entomological profession reoriented its activities when hostilities broke out. A Special Joint Resolution of the American Association of Economic Entomologists (AAEE) and the Entomological Society of America in December 1941 called for Chief Annand of BEPQ to convene a meeting of entomologists as soon as possible to ascertain the best use of entomological resources for defense purposes.[18] President John Robert Park of the AAEE, in his presidential address on December 29, 1941, called for entomologists to perform public relations work so that government budget makers would know the importance of entomological research to the war effort.[19] Harry B. Weiss, president of the AAEE during 1942, appointed the Committee on Coordination of Entomology with the War Effort on April 20, 1942. In a series of reports, the committee outlined how all entomologists, "who . . . are determined . . . that the present war crisis shall result in victory to the forces of freedom and democracy," could best contribute their knowledge and skill to the nation.[20] The psychology of commitment to total war was further

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[16] Percy N. Annand to Secretary of Agriculture, December 16, 1941, ibid.

[17] Three men headed DIAMA in the critical prewar and war years: Fred C. Bishopp (1926–41), E. C. Cushing (first half of 1941), and Walter E. Dove (June 1942–45). Ruric Creegan Roark headed DII from 1928 to 1952.

[18] "Special Joint Resolution of the Entomological Society of America and the American Association of Economic Entomologists," *Journal of Economic Entomology* 35 (1942): 132.

[19] J. R. Parker, "Annual Insect-Damage Appraisal," ibid., pp. 1–9, presidential address to the fifty-third annual meeting of the American Association of Economic Entomologists.

[20] E. F. Phillips et al., "Report of the Committee on Coordination of Entomology with the War Effort," ibid., pp. 303–5; "Report of Progress," ibid., pp. 468–71; "Report of the Committee on Coordination of Entomology with the War Effort," ibid. 36 (1943): 132–35; "Report of the Committee on Coordination of Entomology with the War Effort," ibid., pp. 135–36; J. S. Houser et al., "Report of the Joint Committee of the

demonstrated in President Edward Oliver Essig's presidential address to the AAEE in 1944, "An All Out Entomological Program."[21]

The DIAMA had a laboratory at Orlando, Florida, that was chosen in 1941 as the major research laboratory for defense-related projects. The initial directions for the laboratory's work came from the armed forces via the Subcommittee on Tropical Diseases of the National Research Council, National Academy of Sciences. Research contracts between BEPQ and the Office of Scientific Research and Development provided funding for research on insect repellents and insecticides, particularly for lice and mosquitoes. By May 1, 1942, bureaucratic details were cleared, and a nucleus of researchers was located at Orlando under the direction of Walter E. Dove and his assistant, Edward Fred Knipling.[22] Orlando thus became BEPQ's center for screening new compounds for insect repellent and insecticidal activity.

By the end of the summer of 1942, the Orlando group had achieved some small successes. In August, MYL powder was recommended to the armed forces for body louse control, but it was effective for only one week, too short a time when men are under the pressure of war.[23] The development of mosquito repellents and mosquito larvicides was not as far along as the antilouse powder. Researchers of DIAMA had recommended indalone to the army as an interim mosquito repellent and felt that esters and alcohols offered

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American Association of Economic Entomologists and the Entomological Society of America on Coordination of Entomology with the War Effort," ibid. 37 (1944): 328–29.

[21] E. O. Essig, "An All Out Entomological Program," ibid. 38 (1945): 1–8, presidential address to the fifty-sixth annual meeting of the American Association of Economic Entomologists.

[22] Walter E. Dove, "Historical References to Man and Animal's Contribution to War Effort," n.d., file: History of Development; series: Entomology and Plant Quarantine, World War II; subgroup: History of Defense and War Activities, 1941–50, RG7NA. Knipling assumed the directorship of the laboratory in June 1942 and guided it for the duration of the war years. He later wrote that the real moving influence in getting the laboratory started came from Col. William S. Stone and General J. S. Simmons (U.S. Army), who sat on committees of the National Research Council. According to Knipling's estimation, the Office of Scientific Research and Development gave the Orlando facility $815,000 between March 1942 and October 1945. In addition, the laboratory received from other agencies equipment, aircraft, personnel, and administrative supervision. The total cost of operating the research station was estimated to be approximately $1 million (Edward F. Knipling, "Insect Control Investigations of the Orlando, Florida, Laboratory during World War II," in *Annual Report of the Smithsonian Institution, 1948* [Washington, D.C., 1948], pp. 331–48).

[23] Knipling.

more promise of good repellent activity than other types of compounds. Although R-612 (2-ethyl-1, 3-hexanediol) was then known to be a good repellent, there were problems in making the compound commerically available. The DIAMA personnel also discussed the possibility of developing nonwettable or floating preparations of Paris green for use against surface-feeding mosquito larvae.[24] Beyond these achievements, however, the Orlando staff had been able to accomplish little aside from the establishment of colonies of mosquitoes and lice for experimental purposes.

The development of the Orlando laboratory in DIAMA was paralleled by the emergence of a severe shortage of agricultural insectides. Federal and state entomologists recognized that the shortage could adversely affect wartime goals for food production. Supplies of pyrethrum and rotenone were of special concern because they were imported and thus subject to disruption by war. Even before the war broke out, there were high-level discussions in BEPQ about shortages of rotenone. There was some thought of encouraging South American countries to increase their production and export of rotenone to the United States.[25] Shortly before the attack on Pearl Harbor, Annand received correspondence from the East African Supplies Board, asking for information on the possible increased use of pyrethrum for agricultural purposes in the United States. Japan was, at the time, the major source of pyrethrum for the United States.[26] By the spring of 1942, just before the planting of the first "war crop," state entomologists and plant pathologists met in Ithaca, New York, and requested BEPQ to issue periodic reports on the availability of insecticides.[27] By the summer of 1942, supplies of rotenone were quite short, and there were allegations that some South American companies were hoarding their supplies in order to force a higher price for the material in the United States.[28]

Roark redirected DII's work to meet the needs of the "victory program of the government." He focused his division's work on BEPQ's two major activities: (1) the search for new materials with insecticidal activities and (2) the collection of statistics on the needs for all types of

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[24] Ruric C. Roark to Percy N. Annand, August 27, 1942; file: Dr. Annand, August 15, 1941; series: P. N. Annand, April 1939, L. A. Strong, August 1940–June 1941, and Cereal and Forage, 1942–51; subgroup: Correspondence of Chief of Bureau, 1934–51, and Administrative Data, 1928–51, RG7NA.

[25] Percy N. Annand to Avery S. Hoyt, July 2, 1941, file: Dr. Annand, April 1939 to August 15, 1941; ibid.

[26] W. H. White to Percy N. Annand, January 28, 1942, ibid.

[27] C. M. Packard to Percy N. Annand, April 29, 1942, ibid.

[28] E. C. Higbee to R. E. Moore, July 29, 1942, ibid. Data collected by the Department

pesticides by farmers in different regions of the country.[29] Roark's staff spent much effort in attempts to find synergists for pyrethrum to stretch the effectiveness of this scarce commodity. By October 1942, DII had conducted 350 tests on houseflies and found six synergistic materials for pyrethrum. The division had also screened 800 new chemicals for activity against phytophagus insects, flies, and roaches.[30]

* * *

The stage was thus set for the arrival of DDT in the United States on October 16, 1942. The laboratories of both DII and DIAMA were set up and operating efficiently, with competent chemists and entomologists. Many compounds were being screened routinely and, if promising, put through a series of tests to determine whether they had any possibility of practical use. The BEPQ felt pressured to provide insect-control materials for both military and agricultural uses. Roark later recorded in a letter to Annand the history of the initial handling of DDT by DII and of the excitement generated by the material:

> When the Geigy representatives called on me on October 16, 1942, they were interested in the introduction into the United States of new *agricultural* insecticides. No mention was made of Neocid, the DDT preparation for louse control and no mention

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of Commerce on imports of pyrethrum and rotenone amply demonstrate the fall in supplies during 1942 and 1943 compared with earlier years (see table).

POUNDS OF PYRETHRUM AND
ROTENONE IMPORTED
(in Millions)

Year	Pyrethrum	Rotenone
1939	13.6	5.9
1940	12.6	6.6
1941	11.0	8.0
1942	9.5	3.8
1943	6.8	4.1

SOURCE.—Taken from Harold H. Shepard, *The Chemistry and Action of Insecticides* (New York, 1951), pp. 147, 159.

[29] Ruric C. Roark to Percy N. Annand, January 2, 1942; file: Insecticide Division, 1934–44; series: Fruit Insects to Truck Crops and Garden Insects, Division Leaders, 1951; subgroup: Correspondence of Chief of Bureau, 1934–51, and Administrative Data, 1928–51, RG7NA.

[30] Avery S. Hoyt to Morse Salisbury, July 2, 1942; file: USDA National Defense and War Efforts (History of), 2d Quarter, 1942; series: Correspondence and Reports; subgroup: History of Defense and War Activities, 1941–50, RG7NA.

of Neocid occurs in the typewritten statement entitled "Properties Claimed for Gesarol Spray and Gesarol Dust Insecticides" that they left with me.

At the time the samples of Gesarol spray insecticide and Gesarol dust insecticide were first received by us (November 3, 1942) the Bureau had revised its policy in testing proprietary products because of the acute shortage of derris, pyrethrum, and the limited availability of other insecticides. The revised policy permitted testing of preparations for agricultural use when sufficient evidence was presented with the samples to warrant it. This was done by the Geigy Company representatives.

Although the two Geigy samples were intended for agricultural use we decided to submit samples to the Orlando laboratory because at that time the Insecticide Division was furnishing most of the compounds and materials for evaluation as lousicides.

Evaluation of the preparations was carried out independently and almost simultaneously at Orlando and Sanford and the results from both laboratories reached us within a week or two of each other. Because of these reports and the interest manifested by both the Orlando and Sanford laboratories, we immediately undertook an investigation of the active insecticidal principle . . . by a series of reactions together with synthesis the structure of DDT was determined. The identity of our synthetic preparation with the active principle in the Geigy preparations was confirmed by insecticidal tests at Orlando. A report on the identity of the insecticidal principal of Gesarol was sent you on March 6, 1943.

On February 26, 1943, Dr. Haller visited the Geigy Company in New York, informed them of our interest in their preparation and inquired as to the possibility of its manufacture in this country. At that time, it was not known by any of us that the Geigy Company had a manufacturing outlet in this country; in fact there was some pessimism that the product (DDT) was impractical because it would be necessary to import it from abroad. Dr. Haller informed the Geigy people of the chemical composition of DDT then known as GNB Conc. and how it might be made commercially. They stated that while they had not been informed about its chemistry that should the product be of value it could be made in this country. Within a few days they confirmed our findings as to the chemical identity of DDT.

The Division of Insecticide Investigations began to make inquiry into the availability of the necessary raw materials, chloral, chlorobenzene and sulfuric acid. In May, 1943, Wm. Lee, Research and Developmental Division, Quartermaster Corps and Dr. Haller visited the Cincinnati Chemical Works, Norwood, Ohio, and encouraged them to proceed as rapidly as possible with the production of DDT at that time called GNB-A. Our observa-

> tions showed that they were not then in production as we had been told but were actively and intensively engaged in developing manufacturing procedures.[31]

Knipling, at the end of the war, also summed up his recollections about how DIAMA had worked with the new chemical from Switzerland in the months immediately after its introduction. The laboratory at Orlando received a sample of Gesarol Dust Insecticide in November 1942 from DII and quickly found that DDT was a good louse powder. "Our chief worry was: Can the chemical be used safely on man? The Food and Drug Administration was attempting to determine the answer to this question. After several months of intensive study they concluded that in dust form DDT was entirely safe to use. By May, 1943, DDT was recommended to the armed services as a safe and effective louse powder."[32]

The effectiveness of DDT as a mosquito larvicide was also quickly established. Christian C. Deonier of BEPQ began work in October 1942 on the development of a larvicide but had not made much progress by February 1943, when DDT was tried for the first time. The DDT was recommended as a larvicide dust in May. Other uses of the chemical were also established by May: DDT residual oil spray for control of flies, mosquitoes, and bedbugs; benzyl benzoate and DDT spray for treatment of scabies. By July of 1943, these uses had been joined by DDT larvicide spray for mosquitoes, DDT impregnation of clothing for louse control, and field tests of 5 percent DDT aerosols. In the latter part of 1943 and in 1944, three other major developments with DDT insecticides reached the stage of recommendation to the armed forces: DDT residual spray emulsion-Triton Z100, control of dog flies by spraying their breeding places, and the use of DDT aerosols in industrial plants for the control of mosquitoes.[33]

Initial production of DDT in the United States was channeled almost exclusively to the armed forces, a policy that, in spite of the shortage of agricultural insecticides, delayed the adoption of DDT for agricultural purposes. In late summer of 1943, shortly after the Orlando laboratory had recommended DDT for certain uses by the armed forces, limited supplies of DDT were sent by BEPQ to various

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[31] Ruric C. Roark to Percy N. Annand, January 6, 1945; file: History of Developments, Entomology and Plant Quarantine, World War II; ibid.

[32] Knipling.

[33] Walter E. Dove, "Contributions to War Effort: Summary of More Important Developments to January 24, 1945"; file: History of Developments, Entomology and Plant Quarantine, World War II; series: Correspondence and Research; subgroup: History of Defense and War Activities, 1941–50, RG7NA.

experimenters in the state agricultural experiment stations.[34] Federal and state entomologists performed some initial experiments, and the results were published in the February 1944 issue of the *Journal of Economic Entomology*. The range of insects against which DDT was tested in 1943 included the oriental fruit moth, the California red scale, various cotton insects, the codling moth, the European corn borer, and others. More extensive tests with DDT came with the growing season of 1944. The BEPQ published on May 1, 1944, a short memorandum for agricultural researchers, "Information on DDT and Suggestions for Experimental Work for Agricultural Purposes." The BEPQ emphasized that little progress had been made toward adopting DDT for agricultural uses: "When the lack of definite information on the agricultural use of DDT is considered, both as to its efficiency against insects under field conditions and as to its effect on plants and plant growths, it is evident that even if the material were available for use against crop insect pests it could not be recommended at this time" (p. 1). The paper urged that experimentalists watch, in particular, for signs of plant injury in treated fields and for signs that temperature had an effect on the insecticidal properties of DDT.

Federal and state entomologists made extensive tests with DDT during the growing season of 1944, but many problems remained unresolved by the fall of that year. In November, the War Production Board informed the DDT Producers Industry Advisory Committee that DDT still could not be recommended for commercial agricultural use.[35] Some of the field studies of 1944 had not repeated the results obtained in 1943, and there were still uncertainties about what percentage of DDT to use and how much residue of DDT could safely be left on the finished commodity.[36]

Despite the initial problems of adapting DDT to use in agriculture, a Special Committee on DDT of the American Association of Economic Entomologists, chaired by Sievert A. Rohwer of BEPQ, reported in December 1944 that the future of DDT looked very promising for an extraordinarily large range of peacetime tasks:

> We feel that never in the history of entomology has a chemical been discovered that offers such promise to mankind for relief

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[34] Fred C. Bishopp to D. L. Van Dine, September 2, 1943; file: Fruit Insects, 1942–51; series: Foreign Plant Quarantine to Fruit Insects, 1942–51; subgroup: Correspondence of Chief of Bureau, 1934–51, and Administrative Data, 1928–51, RG7NA.

[35] "DDT Not Recommended for Agricultural Use," *Oil, Paint and Drug Reporter* 146 (November 6, 1944): 4.

[36] "Agricultural Association Discusses DDT," ibid. (October 30, 1944), p. 3.

> from his insect problems as DDT. There are limitations and qualifications, however.
>
> Subject to these, this promise covers three chief fields: public health, household comfort and agriculture. As public health we include control of the insects which carry diseases that have scourged humanity, such as malaria, typhus and yellow fever. Household comfort is taken to cover such things as flies, fleas, bedbugs and mosquitoes. Agriculture includes not only farms, gardens and orchards, but forests, livestock and poultry.[37]

The optimism of Rohwer and his colleagues about DDT was confirmed in the five-year period following DDT's release for civilian use in the United States in 1945. The zenith of DDT's fame in the control of insect-disease vectors came in 1948 with the announcement from the Nobel Prize committee that they had selected Paul Herman Mueller of the Geigy company as the recipient of the Nobel Prize in Physiology and Medicine. For the first time in history, entomologists envisioned the possiblity of controlling or eradicating malaria, typhus, yellow fever, filariasis, dengue, and other diseases transmitted by insects. At the very time the prize was awarded, the Health Division of the Rockefeller Foundation, the Italian High Commission for Public Health, and the United Nations were in the midst of a joint campaign to rid the entire island of Sardinia of its ancient association with malaria, a project that was largely successful by the end of the decade.[38]

The DDT was widely adopted for agricultural purposes by American farmers and ranchers in the years 1945–50. For example, apple producers in the Yakima Valley of Washington switched almost completely to DDT from the lead arsenate and cryolite (sodium aluminofluoride) by 1948.[39] At the same time, their losses from codling moths dropped from 15 percent annually to 3–5 percent. Economic benefits accruing from the use of DDT were considered high. For example, some Kansas ranchers reported their cattle gained over 2,000 pounds of meat for every pound of DDT used for fly control.[40]

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The successes of DDT during and after World War II had immense

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[37] Sievert A. Rohwer et al., "Report of Special Committee on DDT," *Journal of Economic Entomology* 38 (1945): 144.

[38] S. W. Simmons, "The Use of DDT Insecticide in Human Medicine," in *DDT*, ed. Paul H. Mueller (Basel, 1959), pp. 264–65.

[39] Fred C. Bishopp, testimony before House Select Committee to Investigate the Use of Chemicals in Food Products, Hearings on Chemicals in Food Products (Washington, D.C., 1951), p. 376.

[40] "DDT Helps Cattlemen," *Oil, Paint and Drug Reporter* 151 (March 3, 1947): 38.

impact on the chemical insecticide industry. Scientists in the chemical industry and professional entomologists developed new uses for DDT, and the chemical industry expanded its ability to make the compound. The Cincinnati Chemical Works at Norwood, Ohio, a subsidiary of the Geigy company, began production of the material in 1943.[41] By 1945, fourteen companies were listed by USDA as primary producers of the material, and sixteen companies formulated DDT into insecticides for sale.[42] The total production of DDT by U.S. firms rose from about 10 million pounds in 1944 to over 100 million pounds in 1951.[43] The peak in U.S. production was 1962–63, when 188 million pounds were produced.[44] The number of uses to which DDT was adapted increased and included bulk uses in agriculture and public health and a wide variety of consumer specialty items.

The successes of DDT also stimulated a search in the chemical industry for more synthetic organic pesticides. The Department of Agriculture estimated that twenty-five new pesticides were introduced between 1945 and 1953. The more important of the new insecticides included in the group of materials were chlordane, BHC, toxaphene, aldrin, dieldrin, endrin, heptachlor, parathion, methyl parathion, and tetraethylpyrophosphate.[45]

It is difficult to measure the growth of the new insecticide industry because of the confidentiality in which production data are held by individual companies and because the internal complexity of the chemical industry makes the gathering and interpretation of aggregated government statistics difficult. Nevertheless, the picture that emerged from the 1954 *Census of Manufacturers* dramatized the quantitative changes that had occurred in the chemical insecticide manufacturing industry between 1939 and 1954: the number of establishments producing primarily insecticides and fungicides had

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[41] Buxtorf and Spindler.

[42] Agricultural Research Administration, U.S. Department of Agriculture, "Producers of DDT and DDT Insecticides," mimeographed (Washington, D.C., 1945).

[43] Production and Marketing Administration, U.S. Department of Agriculture, "The Pesticide Situation for 1952–53" (Washington, D.C., 1953), p. 7.

[44] Economic Research Service, U.S. Department of Agriculture, "DDT Used in Farm Production," Agricultural Economic Report no. 188 (Washington, D.C., 1969).

[45] Production and Marketing Administration (n. 43 above), p. 4. J. V. Sherman predicted in 1945 that the growth of the chemical industry would depend on research and development expenditures for new products ("New Products Assure Growth in Chemical Industry," *Barrons* [February 19, 1945], pp. 9–10). An in-depth examination of Merck and Co., Inc., by *Fortune* noted that Merck sales jumped from $20 million in 1939 to $61.1 million in 1946: "Practically all the increase came from the new products [synthetic vitamins, sulfa drugs, DDT, and the fermentation antibiotics (penicillin and streptomycin)], which were also responsible for most of the company's comfortable $6 million profit last year" ("Merck Means Over 1200 Fine Chemicals," *Fortune* [June 1947], p. 104).

increased from eighty-three to 275, the value added to the materials by the manufacturers increased from $3.8 million to $62.1 million, and the total value of the shipments from these manufacturers had increased from $9.2 million to $174.6 million.[46]

More important than mere growth of the insecticide industry is the idea that DDT and the other new chemicals exerted a powerful influence on the shape of insect-control technologies in the postwar years. In 1943, Percy Annand predicted that the effect of the war on postwar insect-control technologies would result from three major events: (1) the time required to introduce new chemicals, especially DDT, was shortened; (2) research efforts of long duration on the biology of insect pests were disrupted and changed to the search for immediate solutions for short-term military purposes; and (3) indirect effects such as increases in airplane transport and new patterns of commerce altered the nature of insect-pest outbreaks.[47] Of these three events, the first two had the most pronounced direct effect on the types of insect-control technologies that became prevalent after 1945.

Chemical control technologies were the type most immediately altered by the invention of DDT and the other synthetic organic compounds that followed. In general, the use of older compounds decreased, and the use of the new synthetic materials increased. For example, DDT and BHC were influential in reducing the use of lead and calcium arsenates in the United States. The total amount of insecticide used per year increased.[48] Not only were older chemicals replaced by newer ones, but the new inventions were sufficiently cheap and effective to warrant adoption for control of insects not previously considered to be subject to chemical control. For example, the cheapness of DDT caused forest insect-control methods to shift from cultural practices to chemical methods.[49] Similarly, the widespread use of DDT to control malaria after 1945 resulted from the compound's cheapness and persistence, traits lacked by the older insecticides. In short, DDT's low mammalian toxicity, persistence, cheapness, and broad-spectrum activity made it more useful than any single insecticide that was developed before it.

The fortunes of the biological control technologies, especially those

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[46] Bureau of the Census, U.S. Department of Commerce, *Census of Manufactures: 1954*, vol. 2, pt. 1 (Washington, D.C., 1957). The figures quoted are for firms classified in Standard Industrial Code 2897.

[47] Percy N. Annand, "The War and the Future of Entomology," *Journal of Economic Entomology* 37 (1944): 1–9, presidential address to the fifty-fifth annual meeting of the American Association of Economic Entomologists.

[48] Production and Marketing Administration (n. 43 above), pp. 1, 4–5, 16.

[49] Samuel A. Graham, *Forest Entomology*, 3d ed. (New York, 1952), p. 10.

dependent upon entomophagus insects,[50] can only be said to have declined as a result of the introduction of DDT and the other synthetic organic insecticides. The percentage of research papers in the *Journal of Economic Entomology* on the general biology of insect pests and on their biological control dropped from 33 percent in 1937 to 17 percent in 1947, while the percentage devoted to the testing of insecticides rose from 58 percent to 76 percent.[51] By 1950, Paul H. DeBach of the Division of Biological Control, University of California, Riverside, noted that the use of DDT had resulted in increases in the cottony-cushion scale and other insect pests on citrus; De Bach and his colleagues attributed such insecticide-induced outbreaks of pests to the destruction of entomophagus insects in the citrus groves. He concluded that entomologists should redirect their research toward finding ways to use both chemicals and biological control, rather than relying on chemical control alone.[52] Not only were biological methods of control replaced or disrupted by the use of chemicals, but entomologists who persisted in attempting to develop control procedures using both biological control and chemicals were ". . . ridiculed by the dominating chemical control proponents as a lunatic fringe of economic entomologists."[53]

Control measures based on habitat sanitation and cultural practices were altered by the advent of the new insecticides in a way different from the biological control technologies. The new chemicals did not so much interfere with habitat sanitation and cultural practices as they tended to offer an alternative. For example, the western corn rootworm (*Diabrotica vergifera* [Le Conte]) could be controlled by crop rotation before DDT.[54] Both BHC and DDT were suggested in 1948 as alternatives to crop rotation for control of this insect by entomologists of the Nebraska Agricultural Experiment Station.[55] Aldrin came to replace DDT and BHC as the insecticide of choice in the 1960s.[56] Corn, especially in the corn belt, tends to be a more valuable crop than the alternative crops with which it can be rotated,

[50] Entomophagus insects are those that eat other insects.

[51] D. Price Jones, "Agricultural Entomology," in *History of Entomology,* ed. Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith (Palo Alto, Calif., 1973), pp. 326–27.

[52] Paul H. De Bach, "The Necessity for an Ecological Approach to Pest Control on Citrus in California," *Journal of Economic Entomology* 33 (1951): 443–47.

[53] R. L. Doutt and Ray F. Smith, "The Pesticide Syndrome—Diagnosis and Suggested Prophylaxis," in *Biological Control,* ed. C. B. Huffaker (New York, 1971), p. 5.

[54] E. Dwight Sanderson and Leonard Marion Peairs, *Insect Pests of Farm, Garden and Orchard,* 2d ed. (New York, 1921), p. 144.

[55] Roscoe E. Hill, Ephraim Hixson, and Martin H. Muma, "Corn Rootworm Control Tests with Benzene Hexachloride, DDT, Nitrogen Fertilizers and Crop Rotation," *Journal of Economic Entomology* 41 (1948): 392–401.

[56] Velmar W. Davis, Austin S. Fox, Robert P. Jenkins, and Paul A. Andrilenas, "Eco-

such as wheat, oats, barley, and soybeans; farmers began to prefer chemical control to crop rotation for economic reasons.[57]

The fate of mechanical control technologies after the introduction of DDT and other new insecticides was much the same as that of habitat sanitation and cultural practices; the new chemicals offered a cheaper and more effective way to control insects than did mechanical control. As a result, insect controllers had a strong incentive to switch to chemicals. There are no statistics on the extent of mechanical control practices in the postwar period, but it is likely that mechanical control survived only in small areas such as households or as a byproduct of some procedure performed for other reasons, such as plowing for weed control that yielded some benefits in insect control.

Legal control, the exclusion of insects by quarantines, was the technology most unchanged by the introduction of DDT and other new chemicals. Indirectly, Percy Annand's predictions noted above about the effect of new patterns of insect-pest problems were amply confirmed. The widespread adoption of air travel made the maintenance of quarantine systems more important than ever in order to exclude alien pests from the United States.[58] The administration of quarantines changed only in that DDT and the other new insecticides were adopted by quarantine inspectors to destroy infestations discovered in items of commerce.

The advent of DDT and the other new chemicals elicited proposals for a new type of control technology that was seldom considered in prewar times: permanent control by eradication.[59] The beauty of such a motion was clear. If an insect population could be brought to zero over a large area by the new chemicals, then there would be no further need to use any control methods, save for quarantine to prevent its reentry from some foreign pool.

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Insect-control research and practices in the United States were thus

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nomic Consequences of Restricting the Use of Organochlorine Insecticides on Cotton, Corn, Peanuts, and Tobacco," Agricultural Economic Report, no. 178 (Washington, D.C., 1970), p. 14.

[57] John H. Berry, "Effect of Restricting the Use of Pesticides on Corn-Soybean Farms," in *Economic Research on Pesticides for Policy Decision-Making,* proceedings of a symposium, April 27–29, 1970 (Washington, D.C., 1971), p. 139.

[58] C. L. Metcalf, W. R. Flint, and R. L. Metcalf, *Destructive and Useful Insects* (New York, 1951), p. 354.

[59] Clay Lyle, "Achievements and Possibilities in Pest Eradication," *Journal of Economic Entomology* 40 (1947): 1–8, presidential address to the fifty-eighth annual meeting of the American Association of Economic Entomologists.

reshaped both by the war and by DDT's development and adoption: (1) the success of DDT stimulated the development of other synthetic organic insecticides, (2) old chemicals were abandoned for new ones, (3) chemical control technologies acquired a greater prominence in the total constellation of insect-control technologies, (4) biological control technologies were disrupted, (5) control practices based on habitat sanitation and cultural practices were abandoned, (6) eradication proposals won new adherents, and (7) research problems undertaken by entomologists shifted from biological studies toward studies of insecticides.

To what extent did the reorientation in research and in control practices depend upon the war itself? Another way of asking the question is, Would DDT and the reorientation have occurred in the absence of the war? Although we cannot be sure, it is highly likely that DDT and the reorientation would have occurred even if World War II had never happened. After all, the Geigy company had identified DDT before the conflagration developed in Europe, and there is no reason to think the company would not have promoted its product with vigor. In short, the hope for economic gain might well have eventually led to the same changes in insect control research and practices. The war, however, accelerated the process, specifically by creating three distinctive cultural cues for entomologists: (1) a fervent desire to contribute to the war effort, (2) a reorientation of research policies to meet short-term military needs, and (3) a belief that the work with DDT was a substantial contribution to the war effort.[60] Each factor was an incentive for entomologists to reshape insect-control technologies toward reliance on DDT and other new chemicals. The circumstances of the war thus became an integral part of the emergence of the new insecticidal technologies.

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[60] Knipling assured himself and others that their work had indeed been useful: "The practical use of . . . [DDT] was a notable contribution to the successful termination of the war" (Knipling, n. 22 above).