GUARDIANS OF ABUNDANCE: AERIAL APPLICATION, AGRICULTURAL CHEMICALS, AND TOXICITY IN THE POSTWAR PRAIRIE WEST

by

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B.A., SOUTHERN OREGON UNIVERSITY, 2004

M.A., UTAH STATE UNIVERSITY, 2006

AN ABSTRACT OF A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree

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Abstract

This dissertation contributes to the environmental, agricultural, and technological history of the modern United States by examining pesticide use and the debates surrounding them in the Great Plains from the 1940s to the 1980s. Specifically, it addresses the relationships among aerial sprayers, farmers, agriculturalists, and grassroots concepts of toxicity that emerged from mid-century technological and environmental changes. It argues that pesticides as well as a variety of weeds and insects actively transformed the tools, attitudes, and regulatory policies of their users.

Historians of agricultural chemical use in America have focused on the political debates over DDT, the social activism against pesticides that Rachel Carson inspired with her best-selling book *Silent Spring* (1962), the growth in federal regulatory policy in the 1970s, and the contentious reactions by the chemical and agricultural industries. This study offers a new, ground-level history of pesticides by showing how aerial sprayers, farmers, and agriculturalists developed custom chemical applications and conceptualized toxicity as each related to the technological and environmental changes in the region. Drawing on multiple sources, including agricultural experiment station reports, scientific studies, government documents, farm journals, landowner and aerial spray pilot correspondence, and oral histories, this study explores how local producers changed with their chemicals, spray planes, and pests to develop an environmental ethos that understood toxicity as a synthetic and natural danger. Although opposition to pesticides became central to modern environmentalism, debates around pesticides' effectiveness and dangers did not come only from activists or government regulators. Beginning just after World War II, landowners and spray pilots in the fields and rural airstrips of the

Great Plains took the hazards of agricultural chemicals seriously, critiquing how and why pesticides were used for decades after.

By viewing chemicals, spray planes, and pests, as well as landowners, pilots, and agriculturalists as equal forces in the regional transformation of farming landscapes, this dissertation highlights a new history of pesticides, agriculture, and the environment. Farmers and custom applicators did not simply follow the economic goals of agribusiness. Nor did they dismiss the dangers of pesticides. Rather, they constructed their own standards of injury and environmental risk that stressed accuracy, regulation, and a reasonable certainty of safety—a result of the equally transformational influences of chemicals, pests, and the region. This study finally offers new insights into the creation of national chemical policy and the regulatory debates over pesticides during the 1960s and 1970s.

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Acknowledgments

"Writing," John Muir once said, "is like the life of a glacier, one eternal grind." This dissertation was certainly a slog, but fortunately there were pauses. I must first thank my adviser Jim Sherow. When I came to visit Manhattan, we went hiking together on the beautiful Konza Prairie, where he had me experience how the prairie looks, smells, feels, and tastes (yes, I said taste—beware future graduate students). This trek was one of many in which Jim's unfailing faith in me as a doctoral student, his gentle but direct guidance in writing and thinking, and his kind friendship gave the purpose and clarity that carried me to the finish line. He is a model of what I hope to be as a historian, teacher, and public servant. It has been an honor to work with him.

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Dedication

I dedicate this dissertation to my grandfather Richard Earl Miller, whose love of airplanes, the mountains, and adventure must have rubbed off on me.

Introduction

Drive west on I-70 through Kansas into eastern Colorado, or north into the corn belt of Nebraska, northeast into the Iowa, or south into Oklahoma or Texas, you might see some risky aerial acrobatics usually reserved for county fairs or air shows. From early spring through harvest time you will see Ag pilots spraying pesticides to rid fields of noxious pests threatening the health and welfare of crops throughout the region. They fly low and slow above the ground dispersing poisons over fields and pastures. Although a common sight in the Great Plains, scholars have largely overlooked aerial application and its role in the history of agriculture, environment, and technology. One reason, perhaps, is that pesticides are so tightly woven into the tapestry of postwar American agricultural policies and national political debates about the environment that it is hard to see their distinctive influence among producers, technology, experts, and landscapes at a regional level.

The transformative power of agricultural chemicals for good and ill was a central force in postwar America. A growing culture of mass consumption, expectations of never-ending affluence, and a "Green Revolution" in agriculture abroad all characterized American farm policies that increasingly relied on a chemistry-based abundance. Pesticides helped drive the affluent society, as Harvard economist John Kenneth Galbraith famously termed it, but they also created hazards that threatened its human and nonhuman residents, and the fertility of the land. By the 1960s, the chemical age collided with a new age of ecology in which environmentalists argued that the world—both human and nonhuman—was interconnected and that the use of pesticides, primarily

DDT, traveled from planes onto fields to be absorbed by crops and farmers' bodies and contaminated much more than target areas.

Our understanding of America's chemical past has largely focused on these clear lines of mid-twentieth century environmental critiques over agricultural production. Historians have explored the social, political, and ecological consequences of farm chemicals as part of the larger agricultural reordering that took place after World War II. Many of these studies address the political debates over DDT, the social activism against pesticides that Rachel Carson inspired with her 1962 best-seller *Silent Spring*, or the growing regulatory controls of the Environmental Protection Agency (EPA) and the contentious reactions to the new mass environmentalism by the chemical and agricultural industries. [1]

Less clear, however, is how people viewed chemicals, their applications, use, and control at the ground level. Beginning in the immediate postwar era, farm producers, specifically landowners, aerial applicators, and weed scientists throughout the Great Plains, made efforts toward crop safety and public health by a risk assessment process that they believed balanced economic goals with the well-being of their fields and communities. Healthy crops for farmers or successful spraying businesses for pilots meant not only killing pests but an emphasis on proper application practices, studying the effects of chemical toxicity, and reporting dangerous pilots or shady chemical dealers.[2]

Even as chemicals became a central part of the modern-day environmental critique, debates around their effectiveness and dangers emanated from beyond activists and government regulators. Landowners, Ag pilots, and weed scientists throughout the Great Plains also took seriously the hazards of agricultural chemicals. Beginning in the early years after World War II, they also critiqued how and why chemicals were used. While it is easy to see the linkage between risk and economic performance, farmers, aerial applicators, and weed scientists also expressed concerns about the social and environmental consequences of chemical exposure and toxicity. Although farmers used newer and more chemicals to produce greater yields and aerial applicators worked under increasingly stringent regulations and adverse public opinion to battle increasingly resistant pests, both groups, along with weed scientists, pursued an agricultural health ethic that linked crop safety with public health through technological accuracy.

This dissertation argues that the recognition of pesticides' transformative abilities in a landscape, their hazardous environmental consequences, and the precautionary standards associated with toxicity and health all had postwar, regional origins. In turn these farm poisons shaped the agricultural landscape in the area as well as influenced the kind of application methods and pesticide regulations at the national level. Farmers, applicators, weed scientists, pests, and pesticides were all equal forces in the region's transformation into a chemical-agricultural landscape. The regional progression of aerial application and the synthetic inclinations of farm poisons both reveal that agricultural chemicals were more than used and abused tools. In a very real sense, pesticides engineered the Great Plains to reflect their toxic tendencies. They altered spray equipment, crops, pests, and peoples in ways that reflected their synthetic structures and consequences.[3]

The story of aerial application, agricultural chemicals, and toxicity in the Great Plains identifies most closely with the emerging scholarship known as "envirotech." A growing group of environmental, agricultural, and technological historians have argued that the older and separate accounts of technological advancement, agricultural progress, and environmental predictability needed to move beyond studies of "progress measured largely in terms of the conquest of nature and raw increases in farm productivity."[4]

More recently, historians have looked at how agriculture, technology, and the environment overlap. As Mark Finlay suggests in "Far Beyond Tractors," an evirotech approach is one that "challenges presumptions that technology's impacts on society, the economy, and plants and animals are predictable, deterministic, and unidirectional." Instead, he denies "that technology and the environment are distinct and oppositional historical subjects." Ultimately, this new direction in environmental, agricultural, and technological history seeks "to uncover the reciprocal and interdependent relationships among the living and nonliving components of environmental and technological systems."[5] This dissertation takes a similar focus.[6]

To tell the story of these "illusory boundaries" between pesticides, agricultural production, and technological and environmental change in the postwar Great Plains, each chapter centers on how pesticides remade the grasslands from an industrial agricultural landscape into a chemical-agricultural landscape.[7] Pesticides helped create new application tools and required new expertise from their users. Finally, farm chemicals helped construct an agricultural health ethos and a toxicity standard that redefined what constituted safety and hazard in the fields of the region.

Chapter One, "The Making of a Chemical-Agricultural Landscape," describes how chemical application, beginning with fire and basic synthetics in the nineteenth century and then with pesticides after World War II, influenced the region's producers to achieve a poison-based prosperity. Pesticides offered a potent alternative to the labor inducing land management practices of past decades. However, using agricultural chemicals meant landowners had to work with poisons and not just apply them—now farming the land meant understanding toxicity quotas, label warnings, and application dosages. Farmers also had to study the biological relationships between insects, weeds, crops, and chemicals.

Chapter Two, “Learning from the Noxious Ones,” describes the role of noxious weeds and insects to the region’s agricultural-chemical landscape. These pests had obvious economic consequences but they also presented environmental hazards to fields, pastures, and rangelands. As biological vectors—weeds more than insects—forced farmers, Ag pilots, and scientists into new relationships with their poisons: producers needed pesticides to match the equally injurious plants and bugs that were contaminating their fields. If chapter one considers how chemicals remade the grasslands, chapter two discusses the importance of natural toxicity and the biological relationships between weeds, insects, and chemicals.

Chapter Three, “Spraying the Airplane Way,” treats the agricultural airplane as an outcome of this chemical-agricultural landscape rather than a consequence of wartime action or agricultural production. Pilots in Kansas and other Plains states constantly altered their equipment, flying methods, and chemical selections in response to agricultural, environmental, and technological forces. Aerial sprayers’ early calls for application standards and chemical accuracy besides their interest in pest resistance reveals that the historical development of the Ag plane had much to do with its antecedent interactions with the chemical-agricultural landscape in the region.

Chapter Four, "Marketing Toxicity and Standardizing Risk," shows how the workings of pesticides shaped the marketing of farm poisons to farmers and applicators throughout the Great Plains. Advertisements, spraying handbooks, and personal testimonials all described a kind of chemical conservation that residents understood. Many of these accounts called attention to the farmland toxicity standard—that using pesticides were dangerous, but areas not protected were at risk too. Notions of control, health, and accuracy were emphasized more than eradication or annihilation. Chemical companies sold their poisons by adapting their messages to the agricultural-chemical landscape and the human-nonhuman-technological relationships that appeared, which suggests that the same ability of pesticides to remake the region also remade the messages of chemical companies and aerial operators.

The final chapter, "Warnings, Regulations, and the Politics of Poison," addresses how these advancements and transformations in the region influenced national spraying standards as well as the rising concerns of hazards posed by pesticides in the 1960s and 1970s. Although the region had seen a long-standing effort to study pesticides, pests, and the hazards associated with pilots, farmers, and weed scientists, the formally accepted idea of agricultural health fell under criticism in the *Silent Spring* era. The new environmental health ethos that emerged with Rachel Carson's 1962 book and its influence on the rising environmental movement challenged the precautionary principle of pesticide use. Carson argued that the indiscriminate application of chemicals created ecological hazards and poisoning on vast scale. Farmers, applicators, and scientists responded by continuing to employ the farmland toxicity standard, but modified it according to the new regulations and politics of the era. The chapter also looks at how criminal applicators and formulators shaped these political and policy changes.

By the 1980s, the chemical age met the computer age, allowing both ideas of agricultural health and environmental health to acquire new technologies to guide their principles. For pilots, farmers, and weed scientists, new electronic guidance systems and data processing represented tools that they adapted to fit the use of pesticides in the region and the changing political landscape in the nation.

In short, the boundaries between environment, weed, insect, Ag plane, farmer, pilot, and agriculturalist in the modern Great Plains region were quite illusory indeed. Effective chemical application required an understanding of pesticides, weeds, and insects that went beyond eradication and economic self-interest. Farmers and applicators had to embrace adaptation, selectivity, and toxicity as both the method and consequence of pesticide application. These fluid technological and environmental relationships required new knowledge, collaboration, and regulation—goals that did not always line up with the messages stressed by manufactures or agricultural journals.

This study also contributes to the growing works of environmental historians on ideas about health, safety, and contamination by looking at how farmers, pilots, and scientists altered their ideas about the well-being of the land as the environmental movement reshaped thinking about the role pesticides played in agricultural health. The producer-based ethos continued to identify fields, pastures, and rangelands as threatened spaces but it acknowledged that synthetic poisons could hurt soil fertility, and users' bodies when misused. However, pesticides also protected against a natural toxicity that appeared through weeds and insects.[8]

By viewing the grasslands as a chemical-agricultural landscape that was equally engineered by humans, nonhumans, and pesticides, new historical revelations emerge about the blurred relationships between human environments, technologies, and agriculture as they relate to pesticides and the region. This history also tells us something about how toxicity, health, and risk influenced how farmers, applicators, and scientists managed their fields, pastures, and rangelands—an agricultural landscape that needed to be protected as well as productive.

Notes

[1] For some literature on these debates and themes see Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955–1985* (New York: Cambridge University Press, 1987); Victor B. Scheffer, *The Shaping of Environmentalism in America* (Seattle: University of Washington Press, 1991; Kirpatick Sale, *The Green Revolution: The American Environmental Movement, 1962–1992* (New York: Hill and Wang, 1993); Hal K. Rothman, *The Greening of a Nation: Environmentalism in the United States Since 1945* (New York: Harcourt Brace, 1998); Karl Boyd Brooks, *Before Earth Day: The Origins of American Environmental Law, 1945–1970* (Lawrence: University Press of Kansas, 2009); John Wargo, *Green Intelligence: Creating Environments That Protect Human Health* (New Haven: Yale University Press, 2009); David Kinkela, *DDT and the American Century: Global Health, Environmental Politics, and the Pesticide That Changed the World* (Chapel Hill, University of North Carolina Press, 2011); Alan Marcus, *Cancer From Beef: DES, Federal Food Regulation, and Consumer Confidence* (Baltimore and London: Johns Hopkins University Press, 1994).

For some of the works on Rachel Carson, *Silent Spring*, and Environmentalism see Thomas Dunlap, *DDT, Silent Spring, and The Rise of Environmentalism* (Seattle: University of Washington, 2008); Ted Steinberg, *Down to Earth: Nature's Role in American History* (New York: Oxford University Press, 2002), 247; Also see Daniel J. Kevles, "Greens in America," *The New York Review of Books* 41.16 (October 6, 1994); Linda Lear, *Rachel Carson: Witness for Nature* (New York: Henry Holt and Company, 1997); Robert Gottlieb, *Forcing the Spring: The Transformation of the American Environmental Movement* (Washington D.C.: Island Press, 1993); James Whorton, *Before Silent Spring: Pesticides and Public Health in Pre-DDT America* (Princeton: University Press, 1974); Frank Graham, Jr., *Since Silent Spring* (Boston: Houghton Mifflin Company, 1970).

[2] A similar approach can be found in the history of antibiotics and postwar dairy production. See Kendra Howard-Smith, "Antibiotics and Agricultural Change: Purifying Milk and Protecting Health in the Postwar Era," *Agricultural History* 84 (Summer 2010): 327–351.

[3] This dissertation views pesticides and their active role in shaping the cultural, technological, and environmental contours of grassland agriculture as a manifestation of what Kevin Kelly calls the technium. In *What Technology Wants*, Kelly describes the concept as a tendency with component technologies that accelerate the evolutionary forces within an ecosystem. Human cultures and artifacts play an important role, but the technium, according to Kelly, is created through a variety of living, non-living, and physical forces that move beyond the human intentions to have an "essential propelling momentum" of its own that forms "reciprocal environments for other technologies (179)." According to ecologist Robert O'Neill, in his *Ecology* article "Is It Time to Bury the Ecosystem Concept (With Full Military Honors, of Course!)" an ecosystem is a collection of "interacting populations," which includes animals, humans, plants, as well as physical forces. Yet, O'Neill observes that Homo sapiens have been viewed largely as an external force that derives "goods and services" from various biomes. Instead, their presence and cultures represent a keystone species in shaping the system, displacing current ecological relationships in a landscape with new ones. Put another way, O'Neill compares Homo sapiens as an invasive pest similar to weeds and insects: "If there were ever a species that qualified as invasive pests, it is Homo sapiens…. It is clear that [human beings have] altered the physical environment of the ecological system. We have changed process rates ranging from productivity to dispersal. We have changed ecological structure by eliminating our competition," altering overall, "the stability properties of the system (3279)"

In the context of the Great Plains, a major part of the production agriculture relates to a "pesticide technium" where insecticides and herbicides acted as a keystone technology that followed their own logic. They created new varieties of plants, insects, and agricultural machines. Through their toxicity, pesticides also shaped producers' attitudes and policies toward the grasslands helping to implement a large-scale momentum that "proceeded on its own determination beyond the free will of…humans. (179)." But pesticides also created new pests and spray technologies that were attuned to chemical habitats. Farm technologies, plants, insects, and producers all interacted in patterns that directly related to farm poisons.

The consistent application of pesticides created a collection of insects, weeds, producers, experts, and technologies that interacted and worked in patterns specific to pesticides, converting the grasslands into a chemical-agriculture landscape.

[4] Mark Finlay, "Far Beyond Tractors: Envirotech and the Intersections of Technology, Agriculture, and the Environment," *Technology and Culture* 51 (April 2010): 480–485.

[5] Ibid.

[6] For other works in the Envirotech genre see: Martin Reuss and Stephen H. Cutcliffe, *The Illusory Boundary: Environment and Technology in History* (Charlottesville, University of Virginia Press, 2010); Joe Anderson, *Industrializing the Corn Belt: Agriculture, Technology, and the Environment, 1945–1972* (De Kalb: Northern Illinois University Press, 2008); Alan L. Olmstead and Paul W. Rhode, *Creating Abundance: Biological Innovation and American Agricultural Development* (Cambridge: Cambridge University Press, 2008); Christopher Henke's *Cultivating Science, Harvesting Power: Science and Industrial Agriculture in California* (Cambridge, Mass.: MIT Press, 2008); Randal S. Beeman and James A. Pritchard, *A Green and Permanent Land: Ecology and Agriculture in the Twentieth Century* (Lawrence: University Press of Kansas, 2001). Also see Brett L. Walker, *Toxic Archipelago: A History of Industrial Disease in Japan* (Seattle: University of Washington Press, 2010) and Edmund Russell, *Evolutionary History: Uniting History and Biology to Understand Life on Earth* (New York: Cambridge University Press, 2011).

[7] The term "illusory boundaries," comes from Martin Reuss and Stephen H. Cutcliffe, *The Illusory Boundary: Environment and Technology in History* (Charlottesville, University of Virginia Press, 2010).

[8] For histories of toxicity, risk, and health see Nancy Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES* (New Haven and London: Yale University Press, 2010); Frederick Rowe Davis "Pesticides and Toxicology: Episodes in the Evolution of Environmental Risk Assessment (1937–1997)," (PhD diss., Yale University, 2001), ProQuest (726028421); Jody A. Roberts and Nancy Langston, "Toxic Bodies/Toxic Environments: An Interdisciplinary Forum," *Environmental History* 13.4 (October 2008), 629–756; Mary Dougals and Aaron Wildavsky, *Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers* (Berkeley: University of California Press, 1982); Branden B. Johnson and Vincent T. Covello, eds., *The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception*, ed., Vincent T. Covello, et al. (Dordrecht: D. Reidel Publishing Company, 1987); Baruch Fischhoff et al., *Acceptable Risk* (Cambridge; New York: Cambridge University Press, 1981); Arthur McEvoy, "Working Environments: An Ecological Approach to Industrial Health and Safety," *Technological and Culture* 36, Supplement: Snapshots of a Discipline: Selected Proceedings from the Conference on Critical Problems and Research Frontiers in the History of Technology (April 1995), S145–S173; Angus MacIntyre, "Why Pesticides Received Extensive Use in America: A Political Economy of Pest Management to 1970," *National Resources Journal* 27 (Summer 1987): 534–577.

Chapter 1: The Making of a Chemical Agricultural Landscape

I am PHOSPHORUS. I was ancient when man was created…here when the earth was a gaseous nebula…here to nourish and strengthen…Man fumbled for light…stumbled on the blessings and curses of fire…hands added crude tools…but held on to weapons. Agriculture without me is nothing…the Greeks used bones, not knowing my presence. Farm, plant, home and life are …because I am present. I was under man's feet…building up for the day when he should awaken….he was mine…I was his. Out of the alchemists' fire I came…strange…light bearing….unwanted. The staff of life…the metal of manufacture…the fabric of garments. My children catalyze, synthesize…hopefully civilize life. Like the phoenix of old, my ashes go on in a cycle of use and disuse. Matches, machines, man…all need my talents. From the heat of arc fires I flow in rivers of industry to the hearthstone of man. White plumed am I…acidic at times…neutral or caustic at others…but a servant of man when properly handled. I am on to new things. I am PHOSPHORUS. [1]

From *Manual on Phosphates in Agriculture*, Vincent Sauchelli, 1951.

Technology is not the mastery of nature but of the relations between man and nature. [2]

Walter Benjamin*, Reflections*

In the postwar era Great Plains, farmers in the region constructed a chemical-agricultural landscape that was ready to produce for a growing and abundant nation. A new pesticide revolution was coming to the area, one that would significantly improve farm production, reduce labor, and generate an agricultural plenty. Potent insecticides and herbicides were finding their way from America's battlefields to its farms. They could protect fields from old enemies and prevent new threats. As the *Kansas Farmer* proclaimed, the grasslands were ready to work alongside producers to increase America's "energy, initiative, and wealth"—an abundance that needed to be protected from pestilence and disease. Reclaiming the land, according to the article, required a joint effort between farmers, chemicals, and grass:

> Let me work the miracle of changing soil and water, sunlight and air into a living, growing plant. Let my roots reach into the good earth to gather calcium, phosphorous, other minerals and nutrients. Let me store these growth elements in my leaves and stalks. Thus, I become the source and supply of food for livestock.

> When eaten by grazing animals I become bone and flesh, hide and wool. I become meat and milk, man's finest protein foods…foods that develop the body and mind of man…that contribute greatly to the energy, initiative and wealth of America. Let me work on the 779 million acres of America's grassland…much of it land that can produce little else of food value.
>
> Again I say—I am the grass, let me work. But give me a helping hand. Let me grow in place of worthless weeds and brush…on land that never should be cropped. Put me back on land that never should have seen the plow. Give me lime, fertilizer, water and care, and I will work hard for you. Let me work for you as your humble but mighty friend.[3]

This "chemical revolution" in the postwar era found its origins in a much older, farming mold that had transformed American agriculture decades earlier. The industrial revolution of the early 1900s that remade America's urban cities also flowed into the country's fields. Harvesting the grasslands for profit was the central goal. Yet as industrialism converted farmland into large-scale production sites, landowners found themselves as part of a system that changed how they viewed their fields, communities, and families. The tools of the factory and the ethos of efficiency were translated into the countryside.

New machines, scientific studies, speed, and specialization characterized this farming transformation. Many historians have identified the incorporation of industrial ideals, actions, and tools, as the "Second Agricultural Revolution." As historian Deborah Fitzgerald explains in *Every Farm A Factory*, "the dramatic changes in twentieth-century farming were usually described as stemming from the twin forces of science and technology, in the form of tractors, hybrid seeds, pesticides, electrification, and so forth. Yet no single innovation created the revolutionary context."[4] Instead, they came from a host of "technical, social, and ideological relationships that both created and sustained the change. Each innovation depended on the other…when a farmer adopted a tractor, for example, he tacitly adopted a whole host of other practices and entered into a new set of relationships."[5]

The intricate web of growing farms, big machines, and productive spaces converted wild grasses into fuel and helped recast the Plains environment into an agricultural landscape that reflected the country's larger industrial turn. The changes in farming machines and the producer attitudes around their use, however, were not monolithic. Although Plains farmers, for the most part, looked favorably on new tools available to them, they remained ambivalent about incorporating them into their daily lives. Cost, production quotas and regional and environmental diversity all factored into the varied ways landowners used tools and viewed the land. As Fitzgerald makes clear, "The sheer diversity of landscapes and climates in America, as well as the diversity of crops and livestock and humans, discredits the idea of a monolithic American agricultural aggregate."[6] The notion that farmers all made similar decisions, acted in similar ways, and encountered similar results fails to take into account the social, political, and ecological diversity that accompanies the region. It cannot be assumed, then, that farmers working the cotton fields of Texas or Oklahoma carried the same ideas and attitudes of landowners in Kansas, Nebraska, or Iowa.

This variety of forces, as Fitzgerald stresses in her book, did lead farmers toward standardization, rationalization, expertise, and mechanization. Dealing with diversity, whether crop-price variances, insect and weed invasions, disease, or erratic climatic changes, moved farmers toward these forces of industrialization: "for some it was a principle that unified a disparate collection of observations, practices, and problems; for others it was a road map that offered directions from old-fashioned traditionalism to modernity. For still others it was a mantra that promised far more than it could deliver."[7]

So how did the agricultural industrial ideal and landscape that Fitzgerald outlines change with chemicals after World War II? In the Great Plains, insecticides and herbicides created a new farming landscape by generating new species of insects, weeds, producers, and tools. Although chemical agriculture inherited many of its traits from industrial forces of past years, it also emphasized new views, values, and methods that were specific to the presence of poisons. Chemicals may have built on older visions of farmland abundance and industrial might, but they also expanded the social, economic, and environmental boundaries of what made farms modern and profitable. This new combination of biological and synthetic innovations raised the risks and dangers of production agriculture along with its rewards. Farmers, aerial applicators, and agriculturalists throughout the region embraced the promise of a chemical-agricultural abundance. They soon learned, however, that pesticides were tools that were ineffective at certain times and unruly at others—while producing new farm technologies, specialists to apply them, social policies to address their effects, and new pests that could stand against them in the field.

The Emergence of Chemical Agriculture

Understanding how pesticides became active participants in creating the postwar farming landscape first requires a look at the historical interplay between culturally driven visions of agricultural abundance, early methods of pest-control such as fire, and the environmental realities of the Great Plains region. Pesticides' ability to both protect and produce confirmed long-standing visions of the grasslands as a region of plenty for modern America. Since toxic dusts and sprays were highly selective in how they interacted with insects or weeds, farmers, applicators, and agriculturalists discovered new possibilities in managing their wheat, corn, and cotton fields in a region marked by constant and violent change. Farm chemicals represented the next stage in pest control but their ecological presence increasingly shifted farming on the Great Plains toward a distinctly poisonous process.

Early Applications of Fire

One of the first major agricultural technologies used on the grasslands was fire. Like postwar pesticides centuries later, early fire applications selectively altered the grasslands, creating a landscape that allowed humans to manage it for various agricultural outcomes. Burning of the prairies had both natural and human ignition sources, and most scholars agree that its presence helped design a region that convinced many European settlers to proclaim: "when we first come here it all looked like prairie land almost."[8]

The Great Plains, as historian Julie Courtwright aptly notes, is an "environment particularly friendly to fire."[9] Climatic variability, plant migrations, and land management by Indian peoples all helped create a landscape that was both fertile and flammable. Because much of the region often went from wet periods to dry and back again, fire became a primary tool in grass production. On the eve of European contact, the Great Plains, with the exception of occasional woody inlets that were protected from fire spreads, was a landscape managed and engineered by fire. This "common chemistry of carbon and oxidation and common geographic region [with a] common origin," as historian Stephen Pyne suggests in *Fire in America* helped the Great Plains transform from the early Holocene (10,000 years ago) landscape that was semi-open forest into an expansive grassland that was largely treeless with occasional woody escarpments protected from prairie flames.[10]

For fire to be an early "master of the Plains" from pre-Columbian contact to the nineteenth century, as Frederick Law Olmstead commented in his 1857 account, *A Journey Through Texas, or, A Saddle-Trip on the Southwestern Frontier*, required a variety of climatic changes that worked alongside heat-based chemical changes to create a new biome.[11] Botanist David Axelrod noted in his study of Central North America that fire had a considerable role in the spread of the grasslands, but that other factors, specifically the increased aridity and climatic fluctuations during the Miocene and Pliocene eras proved equally influential: "The rise of the grassland biome was thus due to occasional periods of increased aridity that restricted forests and woodlands and favored grasses and forbs; to increasing drought west of the 100th meridian which created a flammable source (dry grass); to natural and man-made fires on the relatively flat plains over which fire could spread uninterruptedly; to fire that destroyed trees and groves on the flat grasslands, restricting them to rocky ridges removed from fire; and probably also to large browsing mammals (many now extinct) that may have destroyed scattered trees and shrubs on the interfluves during the Altithermal."[12] The combination of these climatic changes, animal distributions, plant migrations all created an agricultural ecosystem that required its inhabitants, humans and non-humans alike, to adjust their living habits, farming practices, and communities with periods of drought or precipitation to achieve stable crop production. Indian peoples used fires as an agricultural implement to fertilize lands, control pests, and clear brush in order to manage areas for reliable food production. As Pyne points out, farming with fire in the grasslands was a "precondition to successful habitation on the plains and prairies; even nomadism was in part an adaptation to fire, both natural and anthropogenic."[13]

Burning cycles, for the most part, followed the seasonal changes of the region. Fire kept soils fertile and animal populations controlled in a region that was constantly in flux. Variations in precipitation with years of rain or drought, the encroachment of invasive insects or weeds, and variability in animal populations as well as soil types meant fire applications could not be uniform nor could they be used only for one task. Dynamic burning practices also reflected the different economies of Indian peoples. Fire hunting, for example, had a different purpose and ecological consequence than applying fire for agricultural purposes. Those groups farming with fire found that burning grass in the first year brought the best yield. Its removal of woody plants and trees and converting them into ash typically brought a good harvest. By the second and third years, however, new plants and animals begin to reassert themselves on the landscape, requiring another burn.[14]

Agricultural fire also helped control insects and weeds. The ability of pest communities to survive seasonal ignitions, whether farm-based, hunting-based, or natural (lightning strikes), depends on the variability of the burning regime. Since many of the insect eggs along with their weedy habitats are destroyed during burning events, the problem of infestations and resurgent generations would come later, when fires were squelched rather than applied as part of the domestication process.[15]

Brevet Major and Assistant Surgeon George Sternberg noticed in 1879 that much of Kansas' fertile grasslands came from using fire to control invasive pests. He would also note, however, that fire agriculture was a destructive enterprise that could not continue as the grasslands transformed into an agricultural landscape.[16] Sternberg was making his way across the Great Plains to Fort Riley, Kansas where he was stationed for a period of time. During his explorations, Sternberg studied the variety of soil types, varieties of grasses, animals, and insects that he encountered and sent reports into the *Junction City Union* newspaper.[17] He noted in his February 1879 report that part of Native American land management included using fires to safeguard the land from destructive insects and fungi. He wrote:

> the wild game of the country is his crop. Autumnal fires were his reapers, to aid in collecting and harvesting. Much evil was done; also some good. Let us examine the matter a moment. Indian countries are clean countries. No muddy roads…No underbrush or decayed logs and rubbish in their woods, for the annual fires clean up everything, leaving but the greenest trees with thick bark….This style of farming is exhaustive and destructive, tending to sterility where sterility is possible. Yet though he exhausts the surface and banishes the rains, the Indian does not exhaust the soil below the surface, for he does not stir it. And in destroying everything and seeding nothing, he invariably delivers his country into the hands of white men, free from those noxious insects, which prey upon the grains and fruits of civilized culture.[18]

Albert Richardson also had observed a few years earlier, in the summer of 1866, that prairie fires were quite effective against an onslaught of grasshoppers. Richardson, famous for his reporting on the slavery controversy, was living in the Kansas territory during the late 1850s.[19] With "Bleeding Kansas," as a violent preamble to the larger national conflict, Richardson's reporting on the pending conflict and his free-state loyalties propelled him to regional prominence.[20] During his explorations in the Great Plains, Richardson noted in *Beyond the Mississippi: From the Great River to the Great*

Ocean, Life and Adventure of the Prairies, Mountains, and Pacific Coast that fire was one of the key tools for pest control.[21]

In an excursion to Nebraska, Richardson encountered a grasshopper infestation that seemingly threatened the "vastness of our domain, our pageants of beauty and sublimity, our abounding resources, and our great destiny."[22] Richardson reported that a column of grasshoppers suddenly appeared near Fort Kearney that was "seemingly one hundred and fifty miles wide and about one hundred deep….Some farmers burn the prairies before them. This confounds the troublesome visitors; like human armies, finding their supplies cut off, they make forced marches. They strip to skeletons shining cottonwood leaves...They feast upon tender leaves and milky kernels of green corn. Witnesses [say] that in some places they eat ripe corn, cob and all!"[23] He also wondered in his account, if anyone would design an aerial farm tool that could compete against pests like grasshoppers: "What genius will achieve immortality by learning from them to construct a flying machine, as Sir Samuel Brown invented the suspension bridge from a spider-web across his path?"[24]

The early use of fire represented an important stage in the region's agricultural and pest control practices. As both Indian peoples and Euro-Americans discovered, fire provided a crucial purpose in preparing and renewing prairie lands for productive harvests later. Its removal of brush and wild grasses, the chemical reactions between ash and soils, and the control of invasive weeds and insects represented an early version of pesticides that would be as active and transformative. As Pyne suggests, "even agriculture has turned away from fire as a source of fumigation and fertilization in favor of chemical pesticides, herbicides, and fertilizers (in effect, using fossil biomass as a kind of fossil fallow)."[25] Fire's ability to control insects and weeds helped design a landscape that was profitable and productive. However by the nineteenth century, the agricultural abundance that came by fire also encouraged the tools, trades, and industrial ideas that would, by the nineteenth century, to a complete "ecological unraveling" of the Great Plains.[26]

Garden Visions, Farming Systems, and Chemicals

As historian James Sherow observes in *The Grasslands of the United States*, the ecological relationships that Europeans first encountered—"relationships resulting in lands teeming with bison, elk, deer, cougars, wolves, and prairie dogs providing game for hunters; river valleys populated by peoples practicing all forms of agriculture and living in a variety of communities; arid grasslands effectively harvested and hunted by peoples living near streams and wetlands"—were difficult to maintain.[27] The massive migration of peoples, plants, and profiteers in the three decades after the Civil War proved a strong domesticating force in the grasslands. The transformations of settlement, land-use, and technological innovation significantly replaced wild grasses with corn and wheat. Cattle populations rapidly expanded. Bison herds declined. And insects and weeds arrived to claim ecological homesteads of their own. Together these shifts created a new agricultural habitat that reflected Euro-American market-views and the urban pulls of industrialization.[28]

The grasslands that fire helped create were quickly being consumed by cattle, railroads, and land-grabbers in the name of profit. Idealized visions of the grasslands promised by newspapers, railroad companies, and other promoters encouraged developing a "garden" that would serve the country and the world. This version of abundance caricatured in Kansas artist Henry Worrall's "Droughty Kansas" or documented in historian Henry Nash Smith's *Virgin Land* articulated a cultural continuum that would carry over into the twentieth century.[29] While the Plains region was mainly known in the early part of the nineteenth century for its aridity —a "Great American Desert" that needed to be conquered—a new vision emerged in the late 1800s that advertised the grasslands as a garden region where: "the grass, water and timber of several varieties are found in abundance, and all of excellent quality; small fruits abound; game is plentiful. The valleys are well adapted for cattle raising or for agricultural purposes, while the scenery is lovely beyond description."[30]

Both concepts of agricultural opulence, however, included improving and dominating the land through technology. As Governor John Martin proclaimed in his 1886 celebration address of Kansas statehood:

> Labor-saving machines sweep majestically through fields of golden wheat or sprouting corn, blooded stock lazily feed in meadows of blue stem, timothy or clover, comfortable houses dot every hill-top and valley, forests, orchards and hedge rows diversify and loveliness of the landscape, and where isolation and wildness brooded, the majestic lyric of prosperous industry is echoing over 81,000 square miles of the loveliest and most fertile country that the sun lights and warms… [Kansas] has become a prince, ruling the markets of the world with opulent harvests.[31]

New implements such as harvester combines and steam-powered threshing machines built on older farming implements to bring the Great Plains states into an industrialized agriculture by the early twentieth century.[32] As many living in the region realized, however, the "garden in the grasslands" had to be constantly maintained because farming there meant always being in motion.[33] The environmental knife's-edge of drought and rain cycles translated into either strong or weak crops, since planting both corn and wheat required a reliable water supply. Price variances and pest attacks only added to the adaptive strategies required of those working the land.

Indeed, the agricultural prosperity that farmers were seeking, the technologies they used, and the ecological dynamics of pest communities in their fields meant constantly making changes. The construction of chemical-application machines at the turn of the twentieth century illustrates this point. Horse-drawn sprayers or mechanized grasshopper collectors, were by design, innovations that allowed landowners to regain control of their fields.

The "hopperdozzer," for example, was essentially a field scraper that was modified to catch and kill grasshoppers. According to a USDA study in 1891 on regional pest control methods, "it was usually drawn by hand, though several pans were frequently bound together and drawn by horses; while, in some instances, certain improvements in the way of mounting on wheels, so as to be pushed from behind, were also adopted."[34] Federal investigators also noticed that farmers created a variety of other machines for chemical application: "We saw some with a wire screen or cover to the back, so that the insects might be secured when the pan was not in motion…We also saw lime and kerosene mixed so as to form a mortar substituted for the coal tar."[35]

Farmers also wrote to local agricultural periodicals to describe their newest modifications. A correspondent of the *Kansas Farmer* in June of 1877 commented that farmers seemed to be developing new contrivances for every new attack: "I cover the surface with tar (common), which will burn and is poison to the hopper. The machine tilts over the axle and can be made to scrape the ground or raised to pass over grain or obstruction." The "dozer," the farmer reflected, "is a perfect success, gathers the hoppers almost as clean as a reaper will cut grain; none get away. One week's work and 4 gallons of pitch tar will clean the worse hoppered 160-acre farm in Minnesota. At one priming with tar yesterday my man caught about an hour a half bushel, estimated to make 10 bushels when grown."[36] Landowners often took chemicals like Paris Green, which was a derivative of copper dye, London Purple, which was a product of lime and aniline dye, mixtures of lead arsenate and sulfates of copper and lime or more simple combinations of salt, lime, and sulfur to spray on their fields. They mixed them according to what they had read in reports or had personally tested.[37]

These early machines and chemical blends provided only limited success. These tactics alone would not suffice, especially when it came to locusts. The USDA observed, "we had a number of experiments made with different insecticide mixtures in 1876 and 1877…The only substance which indicated possible results of value was Paris green [when] it was mixed with twenty to thirty parts of four it was sprinkled on the ground, and many locusts were attracted to and destroyed it."[38] The report, however, warned farmers that these measures alone would not be enough. "This mode can not be compared with many of these already described. Its use against the young locusts is practically of little value, because of the excessive numbers in which they usually occur."[39]

The report went on to recommend a combination of diversified agriculture tactics to achieve prosperous harvests instead of simply planting the same crop each year. The heavy crops that have "stimulated land hunters [to] have a passion for immense tracts and great wheat-farms" only encourage the ravages of insects. "It must necessarily follow that the more extensively any great crop is cultivated to the exclusion of other crops the more will the peculiar insects which depredate upon it become unduly and injuriously abundant…Alternate your timothy, wheat, barely, corn, etc., upon which it flourishes, with any of the numerous crops on which it cannot flourish, and you very materially affect its power to harm."[40]

Figure 1. Horse Drawn Sprayer for crops,1891. Reprinted from USDA, "The Hop Plant-Louse and the Remedies to be Used Against It," *Circular No. 2, Second Series* (Washington, D.C.: June, 1891), Plate 1.

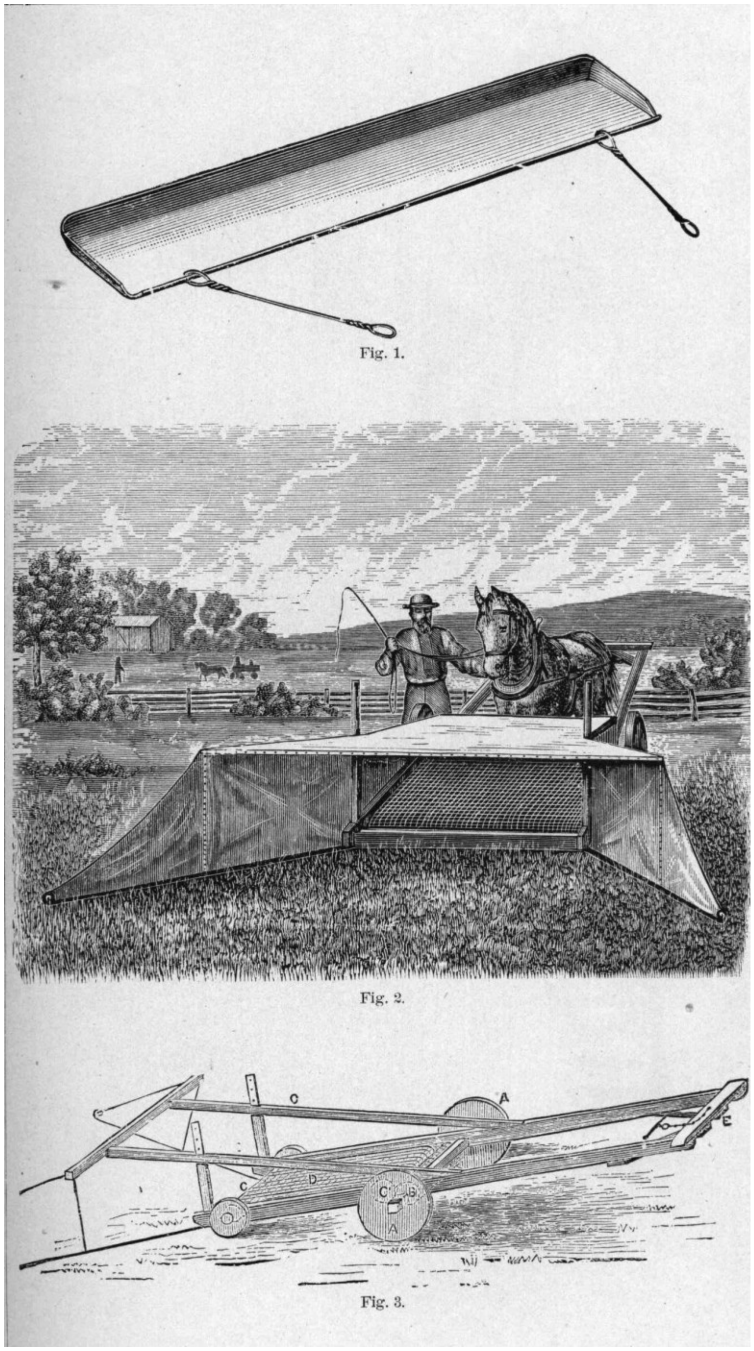


Figure 2. Various mechanical versions of “hopperdozzer,” 1891.Reprinted from “Destructive Locusts: A Popular Consideration of a Few of the More Injurious Locusts (Or “Grasshoppers”) of the United States, Together with the Best Means of Destroying Them,” *USDA Bulletin No. 25* (Washington, D.C.: GPO, 1891).

As farmers utilized a variety of innovations approved by both regional and federal agencies, local entomologists like Charles Riley of Missouri and Roger C. Smith of Kansas studied the toxicity of these early chemicals and pursued biological controls. Both men argued for a cautious use of farm poisons, insisting that non-toxic methods were also available to farmers. Nevertheless, throughout the early 1900s, a substantial part of farmers' prosperity came from combination of chemicals and industrial machines such as the reaper, binder, and the combine.[41]

Some farmers and officials did raise early warnings about the consequences of this "manufactured" agricultural prosperity. Prairie fertility, according to these critics, could not exclusively be tied to industrial values of its lands or the mechanized efforts of its peoples. In a 1926 report on the Great Plains, for example, the USDA argued that farming methods and attitudes needed to change. It was a transitional region, according to the report, that failed to live up to the farming boosterism of the past fifty years. The agricultural system ushered in by industrialization in the early 1900s and expanded by World War I was as problematic as it was profitable. The moves toward industrial agriculture, the USDA warned, had contributed to a farming landscape that encouraged speculation, ignorance, and overuse. Hundreds of thousands of settlers in the Great Plains had suffered extensive losses, which were largely due to "(1) lack of experience with the soils, the climate, and the adaptation of crops in this region; (2) the absence of an economic justification for the bringing into agricultural production of large areas of raw prairie; (3) the adoption of a one-crop system of grain farming and the failure to develop the livestock industry in connection with grain production."[42]

The grasslands were desirable, according to the report, largely because of their soil fertility. Open lands allowed farmers to plant in rows and maximize harvests. The ranching industry also benefited from the space. These forces combined to transform wild prairies into a domesticated landscape increasingly overgrazed, overworked, and underappreciated by its landowners. While staple crops like corn or wheat had adapted to the "rough, broken sandy and stony lands [that were] interspersed amongst the tillable lands … [making] them available for pasture for livestock," agricultural profitability was not a sure bet. Grassland agriculture, the report stated, represented a volatile mix of erratic climates, weather, and environmental conditions that could contribute to profitable yields or just as easily bust a farmer. Farmers needed to adjust to the environmental variability of the region. "Closely associated with…the adaptation of crops to the local environment," stressed the report, was the "the selectivity of necessary implements for…handling the crops grown under the[se] conditions …. The extent to which the tractor, the motor truck, and the combine harvester are to be used will be important factors in the selection. The general topography of the farm should [also] be considered in this connection."[43] High yields required high investment, technological innovation, and an understanding of regional environmental and agricultural relationships. Predictable harvests, however, required constant attention to the biological interactions between crops, soil, and climate as well as an anticipation of land and yield prices.

Regional scientists such as Roger Smith from Kansas State Agricultural College agreed. He insisted that farmers in the Sunflower State could not continue producing rough-shod over the land. Landowners had to protect their harvests. Thus, they could not ignore the biological interactions of pests nor could they dismiss the environmental conditions that weakened their crops. Land management had to include an attitude and willingness toward innovation that considered the grasslands themselves, rather than simply their capability to make profits.[44]

More importantly, perhaps, was Smith's insistence that controlling pests required behavioral as well as technological adaptations. Farmers had to understand each individual insect—their behaviors, destructive tendencies, and place in the larger environment—and devise technological solutions. Since each insect created a damage pattern according to its species and biological community, a comprehensive approach against all pests, according to Smith, simply would not work. Rather, they had to diversify crops as well as selectively apply chemicals. Willy-nilly spraying could be as damaging as insect attacks themselves.[45]

Protecting Abundance after World War II

By the 1930s and 1940s, chemicals would acquire a new place in the farmers' arsenal as a new agricultural vision was manifested in the region. The Dust Bowl, the Great Depression, and another war in Europe all emphasized to farmers and agriculturalists that field fertility and abundant crops had to be protected. In order for farmers to keep their fields safe from threats but also fertile, they had to pay attention to what agriculturalists of the period called the "balance of nature."[46] Soil could not just be worked over or plowed under; farmers had to recognize that their activities and a host of nonhuman enemies carried many risks that were not only limited to national price variances or economic input/output ratios. This warning explicitly related to pest control. Keeping the "balance of nature" in a production agricultural context meant acknowledging the potent effects of their new toxic tools and recognizing how noxious weeds and invasive insects threatened the larger farmland environment. Both forces tipped the scales, argued agriculturalists, and farm chemicals represented a tool that could keep the balance so that farmers could continue to venture down the road of abundance.[47]

However, chemicals needed to be used safely and with accuracy. Again Smith's observations provide some insight. His consternation over applications in a 1932 presidential address before the Kansas Academy of Science suggested that a new way of thinking was needed that linked the economic risks of yields to the ecological health of fields and the land. Smith emphasized that this "natural balance" for the Great Plains was one that acknowledged the ecological sensitivities of the grasslands as well as the agricultural production goals of farmers. Smith maintained that all Kansans and residents of the Great Plains for that matter needed a better understanding of their relationships to the grasslands; protecting their fields meant evaluating the vulnerabilities that came with production.[48]

Farmers were some of the "great disturbers" of the land, Smith observed, because their use of the grasslands for profits had encouraged a host of noxious invaders. The problem with weeds and insects, he told the audience, was that they have the ability to adapt faster than farmers or politicians can create tools or policies to stop them. Chemicals, he warned, were promising tools in pest control but they were hard to control. Applying them carried risks that required careful consideration and measure:

> Insect and plant disease problems are actually increasing, both in number and severity in the great plains region. Man, the disturber, will have to employ artificial control efforts for a long time, or be seriously handicapped in his labors. This biological complex reminds us of a complicated and delicate machine in which a slight maladjustment of a part affects all the others. It is as a stone

> dropped into a quiet pool. The ripples travel outward on all sides and upset the grains of sand all along the shore.[49]

Average landowners like James Brazelton in Kansas also worried about the problems of reclaiming lands that had been sprayed or chemically mismanaged. Brazelton blamed excessive spraying of arsenic and lead as the main culprit in a growing number of old croplands that he feared were permanently infertile. Many growers, he wrote the *Kansas Farmer*, had tried to reclaim unusable fields with limited or no success. Their lands are unhealthy not only because of weeds or insects, but "growers here are facing a new and entirely different problem…. There are 'toxic plots' on orchard land where the trees once stood. It has been found virtually impossible to get a good strand of alfalfa or lespedeza on such land. Corn has been tried but does not do well."[50] Brazelton called for increased relationships between state experiment station personnel and producers to develop methods of resuscitating poisoned lands into healthy, productive spaces. "If [agricultural experiment station officials] can say to the perplexed grower, 'here is a crop that we know will grow profitably on your orchard land,' they will be rendering a service that will be most sincerely appreciated."[51]

Many others joined Brazelton in wondering if these new "artificial controls" and their new applications were worth the risks. Writing to agricultural newspapers such as *Capper's Weekly* (Kansas), *Wallace's Farmer* (Iowa), or the *Nebraska Farmer* (Nebraska), landowners requested information about the potency levels of newer insecticides and herbicides, or critiqued the promises made by chemical companies about their product's effectiveness. In Iowa, for example, some farmers measured the financial and the environmental value of these new chemicals. How would they fare against the seemingly ceaseless battle against insects and weeds? The risk of chemical failure or over-application was as dangerous as the plants and insects they were trying to kill. In a 1938 letter, farmer Joe Colon from Gilmore City, Iowa wrote E. P. (Dutch) Sylwester, Iowa State's weed specialist, about the varieties of chemicals to apply on his fields and their chemical toxicity. Worried about the ongoing invasion of weeds in his corn fields, Colon created his own test plots to study the environmental interactions of weed communities, specifically Canadian Thistle. He began a series of experiments to better understand the toxicity and residual chemical effects on crops, weeds, and the soil.[52]

Criticism also abounded in farmers' correspondence. *Capper's Weekly*, responding to landowner uncertainty in 1945, published a highly critical report on DDT, which, in the immediate postwar period, was the nation's most promising insecticide. The paper claimed that the new "magical" chemicals becoming available to farmers were not necessarily what "they were cracked up to be."[53] Insisting that its critiques were based on information gathered from USDA research, *Capper's* warned that the "wonder drug DDT," was not a panacea for all pests. Users, especially farmers, should be wary of spraying it on their fields and in their homes, it concluded: "DDT is very fussy stuff. For use against each bug or insect it requires a different, sometimes complicated application. A person almost has to be an expert to use it properly. For one kind of bug you have to mix it with water. For another you have to mix it with oil. For still another purpose, it must be dusted."[54] The article also stressed that farmers interested in using DDT for their fields ought to learn of its chemical properties and dangers rather than believing the marketing hype.

Since farmers had minimal knowledge regarding the true toxicity of these new chemicals, *Capper's* explained, how could they be sure of its poisonous legacy in their lands, crops, and communities? Also, if DDT and other chemicals were selective to each species of insect or weed, then how could landowners trust that sprayers had the correct mixtures and understood the correct application rates? *Capper's* also insisted that DDT offered no protection against screwworms, heel flies, cattle grubs, chiggers, or the poultry mite—all insects that had long plagued Kansas ranchers. Protecting cattle with DDT only meant at best controlling these pests, but there were no guarantees.

Farmers, the leading agricultural journal warned, also ran the risk of their lands becoming increasingly toxic from repeated spraying operations. Although experiments with the DDT as a "spray for fruits and vegetables [were] still in preliminary stages," tests already showed that "at a rate of twenty-five pounds per acre, [the chemical] retard[ed] the growth of most kinds of beans, onions, spinach, tomatoes, strawberry plants, and rye."[55] In a few years of spraying, "the land could accumulate injurious amounts of the chemical and make it unfit for use. Some injury to squash and cucurbits has resulted from light applications of the material."[56] *Capper's* warned that DDT could also harm farmers' bodies and urged them to lookout for shady chemical dealers who are selling adulterated mixtures and exaggerating its effectiveness and safety: "Little is known about the toxic effect of DDT on humans. So far there has only been one reported death—in England—and there was no official investigation made of it. Some dealers are reported selling very weak solutions and making exaggerated claims for it. To protect themselves, purchasers are advised to read the labels carefully and acquaint themselves with the potency needed for the job to be done."[57]

Many farmers throughout the region worried as much about what they applied to their fields as what was coming into their pocketbooks. A decade of economic and ecological volatility before World War II had taught many about the fragility and vulnerability associated with agricultural production along with the possibility of profits. The war's aftermath only added to these fears. With powerful examples of atomic weaponry, expanding swaths of chemicals with unknown consequences made many farmers in the Great Plains uneasy. Newly designed pesticides offered great promises against weed and insect attacks or disease—a chemical abundance that decreased labor, increased profits, and could protect harvests. But many farmers also wondered about the toxic reach of their new tools. Domesticating the grasslands to make them profitable was still the goal, but producers also carried a sense of risk about their crops relating to insect invasion, weedy expansion, or chemical application.[58]

Aerial applicators worried too. To stay in business, pilots needed the field knowledge of farmers, the science of agriculturalists, and ingenuity of chemical specialists. They had to constantly adapt their spraying methods, chemical mixtures, and mindsets toward chemical, pest, and environmental variability. Their push for standards in Ag plane design, dispersal practices, pilot education, and regulations on spraying and chemicals identifies custom applicators as a product of the region's chemical-agricultural landscape.

The response of weed scientists to the injuries of weeds and herbicides in the region helped fashion two versions of toxicity. The poisonous injuries from chemicals, on the one hand, were dangerous because of their short-term and long-term agricultural and environmental consequences. Weed scientists assisted farmers and aerial applicators in learning the synthetic make-up of pesticides and how they moved through their fields, under the soil, and between plants. But studying the potency of farm chemicals also meant that they needed to understand the equally dangerous toxins and injuries that came from noxious weeds. This "natural" or non-technological toxicity also required the safe application of pesticides in response.

Thus, much like their earlier chemical precursors such as fire or nineteenth century synthetics, post–World War II pesticides were key to production agriculture in the Great Plains. If fire application and suppression produced a landscape that confirmed, at least to an extent, the boosterism of the late nineteenth century and assisted in the revolutionary farming practices of the early twentieth century, pesticides recasted the grasslands again into a farm chemical landscape where prosperity was dependent on the ability to control and protect. Indeed, pesticides became a defining force in farming the modern Great Plains. Their potent and toxic properties represented a cultural, economic, and environmental force equal to that of farmers, pests, and policymakers.

Farmers, Ag pilots, and weed scientists noticed throughout the mid-twentieth century, that the lines between fields, poisons, and tools were not as distinct or controllable as they had previously imaged when it came to pesticide use. In fact their boundaries were quite blurred. Pesticides formed chemical habitats with new producer and tool varieties. The poisons created new types of pests and hazards that made farmlands vectors of toxicity, not just places of production. While these synthetic harvesters were unseen, they carried a potent ecological presence.

Notes

[1] Vincent Sauchelli, *Manual on Phosphates in Agriculture: General Information for Fertilizer Salesman, County Agent, Agricultural Teacher, Farmer, and Fertilizer* (Baltimore, MD: Davidson Chemical Corporation, 1942 [Revised 1951]), 1, from the Donald F. and Mildred T. Othmer Library of Chemical History, Chemical Heritage Foundation, Philadelphia, Pennsylvania.

[2] Walter Benjamin, *Reflections: Essays, Aphorisms, Autobiographical Writings* [translated by Edmund Jephcott] (New York and London: Harcourt Brace Jovanovich Press, 1978), 93.

[3] "I am the grass…let me work," *Kansas Farmer*, 4 March 1950.

[4] Deborah Fritzgerald, *Every Farm a Factory: The Industrial Ideal in American Agriculture* (New Haven and London: Yale University Press, 2003), 5.

[5] Ibid.

[6] Ibid., 11.

[7] Ibid.

[8] Quoted by Dick Rice, interview by Frank Benede, 2 June 1973, Oklahoma Oral History Collection, Oklahoma State Historical Society; also cited in Julie Courtwright's article "'When We First come Here It All Looked like Prairie Land Almost': Prairie Fire and Plains Settlement," *Western Historical Quarterly* 38 (Summer 2007): 157.

[9] Ibid., Courtwright, 159.

[10] Stephen J. Pyne, *Fire In America: A Cultural History of Wildland and Rural Fire* (Princeton, New Jersey: University Press, 1982), 3; Daniel I. Axelrod, "Rise of the Grassland Biome, Central North America," *Botanical Review* 51 (April–June 1985): 163–201; Also see Julie Courtwright, *Prairie Fire: A Great Plains History* (Lawrence: University Press of Kansas, 2011); Richard J. Vogl, "Effects of Fire on Grasslands," in *Fire and Ecosystems* (New York: Academic Press, 1974), 139–182; Chris Helzer, *The Ecology and Management of Prairies in the Central United States* (Iowa City: University of Iowa Press, 2011).

[11] Frederick Law Olmstead, *A Journey Through Texas; or, A Saddle-Trip on the South-Western Frontier* (New York, 1857), 262.

[12] Axelrod, "Rise of the Grassland Biome, Central North America," 164.

[13] Pyne, *Fire in America*, 85.

[14] Stephen Pyne, *America's Fires: A Historical Context for Policy and Practice* (Durham, North Carolina: Forest History Society, 2010), 7.

[15] See Rafael Cancelado and Thomas R. Yonke, "Effect of Prairie Burning on Insect Populations," *Journal of the Kansas Entomological Society* 43 (July 1970): 274–281.

[16]James E. Sherow, *Grasslands of the United States: An Environmental History* (Santa Barbara, Calif.: ABC-CLIO, 2007), 31.

[17]Ibid.

[18] George Sternberg, "The Causes of the Present Sterility of Western Kansas and the Influences by Which It Is Gradually Being Overcome," *Junction City (Kansas) Union*, February 5, 1870, 1. Many segments quoted in Sherow's *Grasslands of the United States*, 31–32.

[19] Conrad Taylor Moore, "Man and Fire in the Central North American Grassland, 1535–1890: A Documentary Historical Geography," (PhD dissertation, University of California, Los Angeles, 1972), 33.

[20] Louise Barry, "Albert D. Richardson's Letters on the Pike's Peak Gold Region, Written to the Editor of the Lawrence Republican, May 22–August 25, 1860" *Kansas Historical Quarterly* 12 (February 1945), 14–57. Richardson's renown ultimately brought him into contact with Horace Greeley in early 1860, as both men met by chance in Manhattan, Kansas to travel by stagecoach to investigate Colorado's gold mines. Touring the mining districts together and publishing a joint-report on the region convinced Greeley to hire Richardson as a correspondent of the *New York Tribune* in 1860 and he returned to Kansas bound for the Colorado gold region once again.

[21] A.D. Richardson, *Beyond the Mississippi: From the Great River to the Great Ocean* (Hartford, Connecticut: American Publishing Company, 1867), 553.

[22] Ibid.

[23] Ibid., 553.

[24] Ibid., 552.

[25] Pyne, *America's Fires: A Historical Context for Policy and Practice*, 17. Also see Richard J. Vogl, "Effects of Fire on Grasslands," in *Fire and Ecosystems*, 139–182.

[26] Sherow, *The Grasslands of the United States*, 28.

[27] Ibid.

[28] Ibid., 76–81.

[29] Homer Socolofsky, "The Agricultural Heritage," in *The Rise of the Wheat State: A History of Kansas Agriculture, 1861-1986* (Manhattan, KS: Sunflower University Press, 1987), 24–27; Henry Nash Smith *Virgin Land*, 123–144; Also see John L. Allen, "The Garden-Desert Continuum: Competing Views of the Great Plains in the Nineteenth Century," *Great Plains Quarterly* 5 (Fall 1985): 207–220; James R. Shortridge, "The Emergence of 'Middle West' as an American Regional Label," *Annals of the Association of American Geographers* 74 (June 1984): 209–220.

[30] Cited in Edgar Irving Stewart's *Penny-an-acre empire in the West* (Norman: University of Oklahoma Press 1968), 184.

[31] Kansas State Historical Society, *Transactions*, III (Topeka, 1886), 376.

[32] Wayne D. Rasmussen, "The Impact of Technological Change on American Agriculture, 1862-1962," *Journal of Economic History* 22 (December 1962): 578-591; William N. Parker and Stephen J. DeCanio, "Two Hidden Sources of Productivity Growth in American Agriculture, 1860-1930," *Agricultural History* 56 (October 1982): 648–662.

[33] David M. Emmons, *Garden in the Grasslands: Boomer Literature of the Central Great Plains* (Lincoln: University of Nebraska Press, 1971).

[34]Untied States Department of Agriculture, Division of Entomology, "Destructive Locusts: A Popular Consideration of a Few of the More Injurious Locusts (Or "Grasshoppers") of the United States, Together with the Best Means of Destroying Them," *Bulletin No. 25*, (Washington D.C.: GPO, 1891), 48.

[35] Ibid.

[36] *Kansas Farmer*, 6 June 1877.

[37] James E. McWilliams, *American Pests: The Losing War on Insects from Colonial Times to DDT* (New York: Columbia University Press, 2008), 94–97.

[38] USDA, "Destructive Locusts." This quote was part of a larger recommendation given by Governor Pillsbury, of Minnesota to all Great Plains farmers recorded by federal officials: "In my former messages I took occasion to urge upon farmers a greater diversification of their crops. The present tendency, I fear is toward an aggravation rather than a correction of the evil referred to….While the cultivation of our idle lands is always desirable, this pursuit of a single branch of farming is to be lamented. And I fear that the expectations of great profits of many inexperienced persons who are drawn knot the movement by excitement is doomed to disappointment. A wiser course is to look to many sources of profit rather than to one….With the production of these, wheat-growing alternates admirably to the advantage of all the products. The continuous cultivation of a single crop must eventually exhaust the soil of the constituents for its profitable growth while it is well known that the finest wheat crops were raised the past year on worn out and abandoned grain-fields which had been resuscitated by a couple of years' rest in grass. It seems almost culpable to import corn, hogs, beans, and other products which can be grown here to perfection. (56–57); Also see Alan L. Olmstead and Paul W. Rhode, *Creating Abundance: Biological Innovation and American Agricultural Development* (New York: Cambridge University Press, 2008), 1–63.

[39] USDA, "Destructive Locusts," 48–49.

[40] Ibid., 56.

[41] Williams, *American Pests*, 81–111.

[42] USDA, "Great Plains Agricultural Development," *Yearbook of Agriculture, 1926* (Washington D.C.: G.P.O, 1926), 406; Farmers' challenges also came from the transformation of the social mores associated with the agrarian ideal. See Clifford B. Anderson, "The Metamorphosis of American Agrarian Idealism in the 1920's and 1930's," *Agricultural History* 35 (October 1961): 182–188.

[43] USDA, "Great Plains Agricultural Development," 408.

[44]Roger C. Smith, "Healthy Crops," (June, 1928), in Smith Archives Collection, Box 8 (unprocessed collection), in the Morse Department of Special Collections at Kansas State University.

[45] Ibid.

[46] This concept did not conform to Aldo Leopold's land ethic concept that emerged in the postwar period. Rather it argued that weeds, insects, and unsavory farming practices shifted the ecological balance in a landscape. This producer's version of balance represented part of an ethos that encouraged farmers to preserve the balance by applying agricultural chemicals. This concept also endorsed aerial spraying as a primary application method. See Senator Elmer Thomas' (D-OK) Senate statement, 4866-1949 Cong. Rec., April 20, 1949 in the Elmer Thomas Papers, Legislative, Box 72, Folder 28, the Carl Albert Congressional Research and Studies Center for Congressional Archives, University of Oklahoma.

[47] See Part I (Freedom from the Plant) and Part II (Chemistry and Civilization) in Jacob Rosin and Max Eastman, *Road to Abundance* (New York: McGraw-Hill Book Company, 1953), 1–33; 113–152. For a continuity view of chemical agriculture to earlier periods of American agricultural abundance see E.I. du

Pont de Nemours & Company, *Chemistry and the Farmer* (Wilmington, DE : E.I. du Pont de Nemours & Company, c1950) in the Donald F. and Mildred T. Othmer Library of Chemical History, Chemical Heritage Foundation, Philadelphia, Pennsylvania.

[48] Roger C. Smith, "Upsetting the Balance of Nature, With Special Reference to Kansas and the Great Plains," *Science* 75 (June 24, 1932): 649–650.

[49] Ibid., 654.

[50] James Senter Brazelton, "Toxic Plots Make Old Orchard Land Infertile," *Kansas Farmer*, 20 September 1941.

[51] Ibid.

[52] Joe Colon to E.P. Swlwester, 1938 in the E. P. Sylwester Papers, Box 1, Folder 1, in Special Collections, Iowa State University: "Dir Sir: I am doing a little experimenting on my farm with different kinds of weeds. And need your help. Could you tell me all the known elements, mixtures and compounds that kill or retard the growth of plants when applied to the leaves and foliage, particularly Canadian Thistle. Thank You, Just a Farmer." For other examples see J.L. Anderson, *Industrializing the Corn Belt: Agriculture, Technology, and Environment, 1945–1972* (DeKalb, Ill: Northern Illinois University Press, 2009).

[53] *Capper's Weekly*, 13 October 1945.

[54] Ibid.

[55] Ibid.

[56] Ibid.

[57] Ibid.

[58] Robert Reed, editor of the *Country Gentleman* attempted to consul readers in a 1953 opinion editorial about atomic technology and chemicals in American agriculture. Reprinted in DuPont's *Agricultural News Letter* 21 (July-August 1953): 57, Reed suggests that excitement rather than fear should occupy landowner's thoughts about the role of agricultural chemistry in their lives: "If peace should eventually be achieved…it would bring the opportunity to do a number of things that need to be done and to open up some new frontiers…As one well-informed man remarked: 'we have been giving so much of our energy and attention to war since1941 that we don't know the peacetime limits of the world we're now living in. We have little idea, for instance, of what atomic energy will mean once we begin harnessing it to civilian uses. The next ten years could be as revolutionary in advances as any in our history. These…opportunities [offer] plenty of reasons for cheer…not fear." For more on the role of atomic power in American postwar society and its relationship to toxicity 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) and Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955–1985* (New York: Cambridge University Press, 1987). Also see Kendra Howard-Smith, "Antibiotics and Agricultural Change: Purifying Milk and Protecting Health in the Postwar Era," *Agricultural History* 84 (Summer 2010): 327–351.

Chapter 2: Learning from the Noxious Ones

It has seemed to us that there are certain chemical groups or types of molecular structures which, because of their known properties, give more promise for weed killing than do many others. We do not mean by this that we can predict that good ones are certain to be found in these categories. Neither are we sure that excellent herbicides will not be found outside these groups. In fact, one point that we want to stress is that there is no known method outside of actual trial on plants in the field to determine the final herbicidal value of a chemical. All too frequently we find that two chemicals structurally related in some important aspect have widely different effects on plant tissues.[1]

L.W. Kephart and S.W. Griffin, "Chemical Weed Killers After the War," in *Proceedings of the North Central States Weed Control Conference*, 1944.

Nature herself holds the key to insect control. Wild plants which are unable to protect themselves are provided with spines, needles, hairs, thorns to protect themselves from insects and animals. They even manufacture repellants such as bitter tastes, odors and even poisons. Many lichens produce insect poisons such as vulpinic acid from wolf moss. Not only have we learned how nature protects but we have learned to use some of the natural plant insect poisons as well as to produce synthetic mixtures for use as insecticides.[2]

Excerpt from "Agricultural Chemicals" in the *Air Applicator Information Series, Volume 1*.

As pesticides reshaped Great Plains agriculture in the postwar era, farmers, scientists, and custom applicators needed an expertise that directly addressed the inner-workings of farm-chemical relationships. Because crops were increasingly engineered by synthetic forces as well as threatened by plants and insects, herbicides and insecticides occupied a keystone place in agricultural production of the grasslands. However, the potency of pesticides exerted a nonhuman counterforce that shaped the landscape and its users—adaptation, selectivity, and toxicity manifested themselves through weeds and insects. Pests not only injured crops but also stole nutrients from the soil and poisoned livestock. Thus, farmers, custom applicators, and agriculturalists had to design compounds that matched rogue plants' and insects' biology, habits, and lifecycles.

Chemicals shifted the lives and communities of pests and their longstanding place in the production-agricultural environment. At the same time, insects and weeds influenced the types and potency of chemicals used on the grasslands. Their shared traits of injury, mobility, and toxicity combined to form the chemical agricultural landscape and directed farmers, spray pilots, and weed scientists. As pests adapted to poisons, producers would have to identify the internal workings of rogue plants and insects and investigate how those traits related to the ecological conditions created by these relationships.

Additionally, the ability of noxious plants and insects to threaten the economic plans of farmers or agriculturalists as well as jeopardize the lives of crops, livestock, and soil fertility highlights a kind of "natural" toxicity that was a part of the chemical-agricultural landscape. The capacity of bindweed to choke crops, the prussic acid and fibrous root systems of johnsongrass that endangered livestock, and the aggressive distributions of musk thistles all emphasized a nonhuman form of "poisonous injury" that came from pests.[3] While insects such as Hessian flies, grasshoppers, European corn bores, alfalfa weevils, cut-worms, army worms, and aphids (to name a few) were not directly poisonous to cattle or humans, they did create the kind of environmental havoc that encouraged farmers, agriculturalists, and aerial sprayers to study the toxic characteristics of pesticides and engineer compounds according to their habits, biology, and lifecycles.[4]

Indeed, these noxious ones' capacity to destroy, poison, and adapt pushed farmers into new relationships with their poisons, required new experts, and stressed collaboration to manage a chemical-agricultural landscape that was as much a vector of a natural toxicity as the growing amount of chemical companies delivering their products to the Great Plains or custom applicators spraying the region's fields. One of these groups—weed scientists—established the North Central Weed Control Conference (NCWCC), to help both landowners and custom applicators find their agricultural-chemical footing in an increasingly shifting landscape of poisonous pests and problems.[5]

Gangsters in the Grass

In 1947 the *Nebraska Farmer* warned farmers that the grasslands were being robbed by weeds and brush in unprecedented ways. Pests forced their way into pastures or fields, stealing the health and life of the land for themselves. "Weeds and brush are gangsters in the grass," the article stated, as they "literally steal your cattle and sheep by reducing the carrying capacity of grazing land or pastures. They rob your soil of moisture and minerals. They choke the life out of your grass."[6] Farmers had to guard their fields from these rogue plants because ignoring them or working around them only brought fields to peril. Weeds, *Nebraska Farmer* continued, are "tough and aggressive. The carrying capacity of a hundred million acres of good grazing land has been greatly reduced…Grass thrives again when the brush is gone. Then, cattle or sheep production can be increased sometimes as much as 300%."[7] Healthy grass was imperative to farmers. Improving their fields not only improved livestock populations but represented the first line of defense against a larger weedy invasion that seemingly attacked at every instance. "Few crops give as great return for a little attention as does grass. A good starting point in an improved grass program is to take steps to control weeds and brush." The first step in reclaiming farmers' fields, according to the article, was collaboration with agricultural experts: “we suggest that you contact your state agricultural college, county agent, or vocational agricultural teacher for further information.”[8]

Many farmers heeded such early warnings offered in agricultural journals and newspapers such as the *Nebraska Farmer* about weeds and chemicals in the immediate postwar era. Landowners had long been searching for better ways to kill injurious plants. Yet, with the rapid expansion of agricultural chemicals and an equally numerous amount of farm poison salesmen touting the “magical” qualities of pesticides, farmers needed a more reliable ecological context to guard their fields.

Chemicals were tricky tools, and weeds tricky plants. Both worked in their own ways toward their own ends. The mobility of insects and weeds as well as their knack to occupy lands and harvest fields for their own communities underscored that achieving agricultural abundance could not simply be about economic inputs and outputs. The problems of toxic residues, chemical carry-over, and mistaken mixtures stressed how quickly this “unseen harvester” was reshaping the grasslands. The longer-term environmental health of fields and pastures were at stake, not just farmers’ pocketbooks.

Even *Nebraska Farmer* warned producers about the growing dangers of weeds, farmers were already pursuing new options and new relationships. Many attended the 1947 North Central Weed Control Conference (NCWCC) in Topeka, Kansas to meet agriculturalists and custom applicators to discuss the latest chemical advancements and the dangers of rogue plants and insects. The rapid progression of the herbicide 2,4-D had nearly usurped DDT in popularity because its toxic selectivity proved much safer to crops than the broad but dangerous complications of dusts. Noel Hanson, an experiment station weed scientist at the University of Nebraska and president of the NCWCC that year, emphasized in his opening remarks that pest control rather than eradication had to be the focus. A change in thinking was a first step in addressing many farmers' and agriculturalists' concerns over the rapidly growing use of new chemicals and their applications. If correctly understood and applied, Hanson told the crowd, pesticides had the potential to create a farming utopia.[9]

However, Hanson warned the audience that pesticides were also potent tools that followed their own path apart from the user's intentions or a company's specifications. Pesticides offered great promises but could also deadly consequences, so new relationships between farmers, scientists, and custom applicators were needed to bring them under control. The weed man's utopia could be realized in just a few years, but "we all know that it will take years of research, education, regulation, manufacture, distribution of materials, and plain good farming in a sound agriculture and industry before the weeds that are now present can be most efficiently and economically brought under control."[10] This weed science vision of agricultural abundance had to be managed according to the qualities and attributes of chemicals and their natural counterparts. Production agriculture could not accomplish sustained harvests, as Hanson saw it, unless agriculturalists, farmers, and custom applicators practiced an agriculture that followed the precepts of pesticides and pests, not merely the economic goals they set for their fields.

The abilities of plants and insects to colonize crops or ranchlands meant a constant ecological competition that very rarely worked in the farmer's favor—that is, until pesticides came along. This union between the cultivation of the grasslands and the more immediate transitions of the postwar era toward production and economies of scale fashioned a habitat that was characteristic of weeds and their relationship with chemicals and the production environment. And the role of pesticides shifted these relationships to reflect the expanding chemical landscape of the grasslands after World War II.

Weed scientists from other states of the Great Plains, such as A.H. Larson of the University of Minnesota, provided some of the first studies on the dangers of noxious plants to not only threaten farmers' economic well-being but also hurt the environmental health of the grasslands. In his 1944 study on the "Habits and Characteristics of Weeds," Larson acknowledged that weeds were organisms of the strongest order. Noxious plants' longevity in a farming environment and capacity to shape it toward its own aims made weeds "among the most successful plants, especially when judged upon the basis of their abilities to perpetuate their own species and take production of the arable land."[11] Farmers needed new knowledge to understand how to employ chemicals effectively. Access to experts was a good start, Larson observed, but the growing groups of specialists, whether weed scientists, aerial applicators, or extension personnel, along with farmers, had to think like weeds, not just kill them.

For Larson, "any attempts to control or eradicate them must be dependent upon knowledge of their structures, and habits or peculiarities."[12] Efforts by farmers, agriculturalists, or custom applicators to rid fields of noxious plants or to establish laws to regulate farmlands could not be carried out, at least effectively, without an understanding of their biological framework, their ability to create larger pest niches in the environment, and their interactions with control technologies. The public, according to Larson, is only now becoming "weed conscious. Little progress can be made until the biological foundations of weed control are better known."[13]

Larson emphasized that weeds occupied a long-standing environmental niche in the grasslands that allowed them to be invaders of the highest order—not simply plants out of place. They challenged the productivity, ignored boundaries, and destroyed land. These kinds of disruptions consistently altered how farmers planted and produced. Weeds also created micro-environments for insects, reduced soil fertility, and threatened other organisms. Chemicals worked, in part, to curb these invasions and disruptions but also offered dangers of their own.

In this sense, Larson desired two types of toxicity that would come to articulate a farm health ethos in the region. This farmland standard had to address a grassland chemical agriculture in which rogue plants could poison similar to the pesticides meant to kill them. Plants could adapt to the poisons, similar to insects, forcing alterations in mixtures, sprayers, and attitudes about their presence as well as their control. Their growth patterns, root systems, seed distributions, and offspring responded to pesticides as if the agricultural poisons were synthetic organisms. Just as weeds selected crops to kill, Larson argued, chemicals would need to selectively go after weeds. He wrote "wheat and other comparable cereals have their associated weeds. Clover and alfalfa have theirs. Annual crops permit some to grow that cannot exist in perennials. Pastures, especially permanent, have their associated weeds, which in turn may be influenced by the animals pastured as well as the ecological conditions of the pasture, and the great degree by the make up of the farmer."[14]

How Plants Turn Rogue

Weeds, as an invading organism, according to Larson, have “learned to get along with these cultivated crops and the conditions under which they grew. Incidentally they no doubt have been selected and reselected by farming practices until the most persistent have become problems in all comparable areas of the civilized world....The ability to persist in spite of efforts to eliminate them, can only be associated with the composition or modifications of the parts of the weedy plant namely the roots, stems, leaves, flowers, and fruits or seeds.”[15] These modifications had much to do with the relationships to “ecological conditions such as climate, wind, soil, and plant associations or to farming practices and livestock.”[16] Thus, Larson insisted that to control farm weeds, “it was quite necessary to be familiar with the life habits of each before much progress can be made.” In other words “we should be familiar with its personality. So far there is too little known about this. What is known is quite fragmentary and poorly dispersed. It should be one of the hopes of this meeting that we set out to do all we can to learn more about these personalities and recrystalize them into a working form.”[17]

Larson’s call to learn the personalities of weeds mainly related to their ecological adaptability, mobility, and toxicity. Many species that plagued the fields and pastures of the Great Plains contained perennial underground roots and stems that allowed them to survive both cultivation machines that were converted to weeding vehicles and the intensified seed prevention strategies recommended by agriculturalists and employed by farmers. Mainly thistles, but especially bindweed, possessed root and stem structures that, once established in an area, could persist from year to year regardless of the prevention strategy. [18]

The ongoing expansion of wheat and cattle production in Kansas, corn in Iowa and Nebraska, and flax and alfalfa in Minnesota during the interim and postwar years created an environment in which rogue plants robbed and poisoned their way across farmlands and fence lines. Early studies with grassland weeds and their noxious properties encouraged a prevention/control framework that helped farmers determine not just the external properties of weeds but their ecological and toxicological properties. Similar to the changes associated with the introduction of pesticides, farmers would have to alter their agricultural behaviors and attitudes toward weeds. [19]

Landowners, however, also had to be careful about how they used their lands, not just keep watch over them. Crop production in fields and grazing in pastures helped noxious weeds create communities that damaged these areas' fertility. A chief ecological characteristic in the early noxious conversion of farmlands was the role of light and its intensity in controlling plant competition. The amount of light was crucial to the ability of "useful plants" to succeed over unsafe plants. Since most weeds grew faster than designated crops, they could assert a canopy that prevented phototropic growth and eventually led to plant death.[20]

For those with pastures or range lands, careful management and livestock rotation were critical to controlling weeds. Since seeds of noxious plants (like all plants) needed light to live, the ground surface conditions required a vegetation density that allowed economic crops to grow but at the same time restricted gestation of weed seeds. Intensive grazing often was the most significant cause of pasture invasions. The reduction of ground covering allowed weed flora to rapidly expand. As ground cover continued to disappear, rogue plants took its place. Once a weedy community is established, other pastures' grasses are forced to directly compete for resources and thus are often displaced. The more often landowners used pastures, the more likely they were creating an environment that weeds could exploit.[21]

Rogue plants not only converted farmlands into nonproductive or even toxic spaces, but they also co-opted production technologies. In this context, another scientist from Kansas State Agricultural College joined Larson and other weed researchers in exploring the transformational forces of invasive plants in the grasslands. Botany and Plant Pathology Professor Frank C. Gates argued in his seminal work *Weeds in Kansas* that rogue plants benefited from the same production technologies that farmers used to harvest their fields. Gates was appointed to Kansas State's Botany and Plant Pathology department in 1919 and remained there until his unexpected death in 1955. Working from earlier extension reports that focused on the principle poisonous plants of Kansas, Gates emphasized in his 1941 book that one of the deadliest relationships in the grasslands was that between weeds and production technologies used in the region's agriculture.[22] Most farmers understand that "animals spread weed seeds," he wrote, but they often fail to realize that "the more mobile power machinery of modern times, as the tractor and combine has stepped up the tempo of weed dissemination. Cultivation and tillage tools, wagons, trucks, autos and even high maintenance machinery act as distributors. River sand used on highways or for construction purposes may be responsible for starting new weed infestations."[23]

The toxicity of weeds could not simply be its poisonous qualities, insisted Gates, but farmers and scientists needed to focus on the injurious and invasive qualities of the plant as part of that standard. Once in a field or grazing area, these plants aggressively took root, immediately going to work building weedy communities. They stole nutrients in the soil, took water from more productive plants, and emitted toxins that killed livestock. Gates also warned that many weed seeds were equipped with their own tools that allowed them to move miles from the original infestation site.[24]

In addition to their mobility, rogue plants created safe harbors for insects and acted as vectors for a variety of crop diseases. According to Gates, farmers and agricultural officials needed to be aware of these associations in order to guard against multiple infestations. Many insects, he wrote, "utilize weeds for food during those times of year when favored crops are not available. This is particularly true of numerous species of aphids and flea beetles. Wireworm, white grub and stalk borer injury is likely to occur where the weed grasses thrive."[25]

Rogue plants, like noxious insects, also selected certain crops to attack and employed their own application tools to invade a farming space. As Larson's study noted, "corn cockle and chess have been spread in seed wheat because it is difficult to remove their seeds from the wheat and because their seeds mature at about the same time."[26] Larson also reported that other types of weeds like horse nettle in Minnesota did not "grow much until after the first of July. When the corn is laid by, it grows rapidly and the normal handling of the crop permits it to ripen seeds without interference and to store up food to initiate the next year's growth."[27]

Larson's study also warned that pasture weeds often were deadliest. These plants' biology included a toxicity that allowed them to expand into arable lands as well as kill livestock outright. Species such as Mayweed, yarrow, oxeye daisy, and Mullein, for example, "have their futures insured by having a bad taste or order, hairy covering, spiny growths, poisonous properties, or woody texture….[they] are usually avoided by livestock because of bad flavors and odors." Also thistles, especially keen to pastures and rangelands, "usually go through to fruition and grow uncontrolled because the spines keep the livestock away." These spines, however, were also "efficient agencies spread by livestock."[28]

Musk thistles were especially aggressive. Their ability to invade a farming space and take over had to do with their own version of aerial application. Once these weeds arrived in a field, they spread very quickly, attempting to colonize as much of the ground as possible. As thistles bloom and go to seed, their reddish, purple flower heads begin to dry, allowing seedlings to detach from the plant. Each thistle converts its flower into a parachute, giving the head a fluffy appearance. At this stage, the plant waits for favorable wind currents and temperature to deploy its seeds into the air with thousands traveling across fences and crops to continue expanding their colonies. Farmers and landowners had a very small chemical application window. A spraying delay or simply missing one plant in a field inspection could mean disaster because a single bloom was enough to reseed farmlands for the next year.[29] Perhaps University of Kansas botanist Ronald L. McGregor stated this threat best in his 1980 report on the thistle: "When this plant has become important enough to create economic problems, it has become naturalized and well adapted enough for [that] environment…thus complete eradication is beyond all available resources."[30]

Larson's study on the habits and characteristics of weeds in the North Central States and Gates's report on rogue plants in Kansas both illustrate an important principle that would guide farmers, custom applicators, and weed scientists throughout the era. The toxic principles of noxious weeds—their ability to poison livestock, hurt crops, steal soil fertility, or become enclaves for insects—and the damage that insects wrought to crops, highlights pests' role in the development of a standard that linked them to the synthetic dangers of chemicals and risks of aerial application. The injurious qualities of weeds and insects did more than threaten farmers' pocketbooks; they endangered overall health of cropland, animals, and the agricultural community.[31]

Plans and Procedures of the North Central Weed Control Conference

Postwar plant pathologists who were also weed scientists such as A.H. Larson (Minnesota), Noel Hanson (Nebraska), Frank Gates (Kansas), Ted Yost (Kansas), and E.P. (Dutch) Sylwester (Iowa) represented a growing group of professionals who, like aerial applicators, were directly associated with chemical agriculture. While a significant part of the toxic principles converting weed researchers into specialists came from weeds themselves, the introduction of pesticides and the tendencies they created in the grasslands forced those researching rogue plants to think like chemicals as well as weeds.[32]

To address the growing complexities around these pests and the chemicals to control them, postwar Great Plains weed experts developed an organization to investigate the environmental, technological, and economic consequences of noxious weeds in the Great Plains. These early weed scientists linked the plans, procedures, and policies of each state, such as Gates's noxious weed list of Kansas with a more comprehensive framework that addressed the many economic and environmental changes that came with chemicals and pests. Additionally, weed experts had to carry a fair amount of entomological knowledge since many of the previously mentioned insects used weed communities as a safe harbor to attack crops. Hanson and the others would have a direct role in encouraging farmers and aerial applicators to study and adapt to agricultural poisons and pests.

A central view that emerged from this cohort of plant pathologists and scientists was an acknowledgment that insects, weeds, and poisons had as much influence over the harvest as their human counterparts. For chemical agriculture to lend a profit, remarked Ted Yost as the first president of the NCWCC in 1945, farmers, agriculturalists, and sprayers needed to realize that protecting the grasslands from rogue plants was more than "just a matter of good farming." Yost, who began his career in Kansas as an agricultural extension agent for the state's agricultural college and ultimately was appointed director of the Kansas Board of Agriculture's Noxious Weed Division, admitted that weed scientists faced an uphill battle to convince many agriculturalists, landowners, and others to conform to a system of controls that accounted for the entomological, chemical, and agricultural relationships included in the postwar farming landscape.

The region and nation's weed problem, remarked Yost, was a serious one, that could not afford such "laissez-faire attitudes." Instead, "we need more and more research. Both State and Federal Agencies should do two things. First, greatly expand their research activities with weeds, and second, better coordinate all weed research work and if possible do the work on the basis of a uniform plan." Every state has its special weed problems, insisted Yost, "why not have a federal weed research worker at each state experiment station, just as is being done on other major problems, such as corn, wheat, alfalfa, insects, plant diseases, animal diseases, etc."[33]


Figure 3. Kansas Weed Scientists Studying a Musk Thistle Invasion, circa 1940s. Reprinted from the Kansas Board of Agriculture *48th Annual Report* (123).

The formation of the NCWCC in early 1944 provided the context for farmers and custom applicators, especially aerial sprayers, to understand the workings of weeds and their noxious tendencies in the evolving farm chemical landscape. The organization also helped give new authority to the study of weeds as an agricultural science. As Yost referenced in 1945, controlling weeds had been considered a rudimentary agricultural task—one that was "entirely the farmer's problem." Weed scientists, then, were considered by many in agricultural extension, at least initially, as studying something that any landowner should already know.

Another Kansas weed scientist, F.L. Timmons, confirmed this professional dismissal in his brief autobiographical account on the "History of Weed Control in the United States and Canada." According to Timmons, the failure of weed scientists to gain acceptance among their peers in farm extension work meant much of the initial research on weeds happened on the periphery of the professional agricultural community.[34] Timmons also began his career in field bindweed experiments that were conducted in 1907 and 1908 in western Kansas. Working at the Fort Hays experiment station, Timmons and his colleagues crafted some of the very first studies on the plant that had long plagued the region's farmers.[35] According to his account, the study of noxious weeds was largely an orphan activity "not recognized as a science," and mainly local. States such as Kansas had basic legislation in place to regulate farmers from transporting or selling crops or grasses that contained weed seeds, providing some context for weed researchers, but those studying noxious plants, according to Timmons, were for the most part, "not considered on a par with research workers in other agricultural sciences. It took considerable courage for a weed worker to admit that he was spending full time or even part time on that problem."[36]

However, a significant shift in institutional acknowledgment came with the ecological influence of chemicals. To achieve correct application rates meant understanding the natural toxicity of weeds to match the synthetic toxicity of their chemicals. A new variety of expert was needed to assist in farming experiments and educational forums specifically dealing with noxious pests. "We pioneers in weed research," Timmons declared, "took pride in being different and in working for national recognition of the weed problems and of what we considered a budding new science."[37]

Research in “ecological, physiological and anatomical phases of weed control kept pace with direct control studies,” which allowed Timmons and other scientists to present their work as agriculturalists that were also chemists and biologists.

Furthermore, weed scientists, like aerial sprayers, carried a farmer’s understanding of the land and region. Certainly this respect for the local landowner promoted amicable legal relationships when it came to noxious weed law enforcement, but weed scientists needed a local view that came with working the land or living in the region. The ability of noxious weeds to quickly overtake fields, pastures, and rangelands and potentially destroy that season’s crops meant that weed scientists required the economic-environmental instincts of a farmer, not just the biological/ecological knowledge of a specialist. The capacity of chemicals to harm also required a local wisdom about the environmental conditions of the grasslands.

According to Timmons, the most dynamic farm chemical that legitimized the weed science profession, at least in the Great Plains, was the discovery of 2,4-D and other phenoxy herbicides from 1942 to 1944. These chemicals shifted the significance of weed science from the agricultural periphery to its center. Due to their selectivity and the ability to limit their toxicity, these new poisons “started weed research on its way as a full fledged new science.”[38] Timmons recalled that suddenly, weed science “became popular and all types of scientists—agronomists, botanists, chemists, engineers, physiologists, and economists—jumped into the whirlpool of activity engaged in trying to learn more about this magic new chemical weed killer and about the whole field of new herbicides opened by its discovery. Many chemical manufacturers developed programs of synthesis and screening to discover new herbicides for a broader spectrum of uses and that were more economical or safer."[39]

The North Central Weed Control Conference largely began as a way to deal with the growing injuries occurring to crops by noxious weeds and the lack of standardized controls as well as knowledge by farmers and officials. Professional recognition was important, which was also a function of the new organization, but for most weed scientists in the grasslands, the environmental and economic health of the region far outweighed any institutional quarrels. For too long, proclaimed C.H. Schrader, director of the society's first conference in 1944, have "too many of the leaders in agricultural education and research drifted along under the impression that our so-called good, ordinary farming practices were controlling weeds. We know that this is not generally true. As a result special weed regulatory and control agencies have been created in many states."[40]

But Schrader, as a representative of the USDA, proposed an even greater goal for the new society. Noxious plants were also toxic to the grasslands and thus a regional plan was necessary, he said, to protect the health and production capacity of the grasslands. He insisted, "we do not wish to dampen the enthusiasm of those states which are now embarking on a regulatory weed program, but we believe that if nothing more should come of this conference than to reveal or to uncover, in its stark relativity, the seriousness of the weed problem and the nature and difficulty of our job, and the necessity of prompt and adequate action, *it will be worth while!*"[41]

Schrader prompted the group of scientists, farmers, applicators, and extension personnel at the fall meeting to create a society that could at once deal with the commonalities of grassland weed pathology while also addressing the region's socio-environmental diversity. "There is hardly a state or locality," Schrader continued, "that cannot contribute something constructive and helpful to the solution of the problem facing us. While our problems are much the same basically, we are attacking them as 12 to 14 or more separate states, with 35 to 50 only partially coordinated agencies, largely planned, organized, financed and equipped differently, with staffs varying widely in size and ability of workers and effectiveness of administration."[42]

Producers were living in a new agricultural environment in which thinking like a weed and an understanding of chemical toxicity was crucial to producing and protecting their fields. Abundant harvests did not come easy and pesticides were not always a magic bullet. For farmers to learn the proper methods of application and maintain an ecological awareness of the dynamic workings of weeds, they needed a social and regulatory framework that could prevent attacks from noxious plants and insects. Ted Yost expanded on this principle in the following year's meeting. "Someone must act as umpire in this situation," he insisted, since agricultural poisons, specifically herbicides like 2,4-D, had the ability to harm not only wheat or corn but the soil and the human communities also concerned weed scientists.

Yost also warned that farmers, custom applicators, and weed scientists were all part a new chemical age of agriculture in which poisons called the shots. Once insecticides or herbicides were unleashed upon the grasslands, they created, "new processes and new situations which most of us are really not prepared to encounter."[43] While producers and agriculturalists were being offered great opportunities to keep their fields healthy or learn more about how to restrain noxious plants, he worried that chemical weed control was quickly falling under the extremely positive claims of chemical companies, whose economic interests often moved well beyond realistic control projections or the harmful effects of their product's application. As Yost put it, "suddenly, we are being offered new concepts of chemical weed control, with ideas backed, for the first time, by the tremendous resources of the chemical industry. What are we going to do about it? Obviously, something must be done or the country will be subjected to the unhappy spectacle of claims and counter claims made by voluble proponents, each insisting that his own product is best. In such a chemical cacophony, the poor hardworking weed man and his farmer friends may well lose their bearings and become hopelessly confused."[44]

A Postwar Weed Program for the Grasslands

Throughout the 1940s and 1950s, weed scientists and the NCWCC developed a weed control plan that attempted to address the economic and environmental tendencies of pesticides and the role of weeds in the region. Key to this program, according to many attendees of the annual meetings of the NCWCC, was variability. Because rogue plants were selective according to the agricultural production environment in how they killed crops, took over lands, and damaged fields, weed scientists insisted that a regional plan of chemical application had to account for the problems of each state, rather than constructing a one-solution-fits-all approach.

All agreed that the application of chemicals had created a landscape that required an expertise in the toxicity of chemicals as well as pests. The first step, according to D.L. Gross, chairman of the postwar weed committee for the Great Plains and extension agronomist with the University of Nebraska, was to recommend weed district supervisors that could instruct landowners in their respective states. Farmers were having tremendous difficulty keeping their current fields and pastures clear of the noxious invaders and working with an agriculturalist that had a comprehension of a weed's biological habits and toxicological properties was a good start.

Landowners had to think like weeds and chemicals in ways that went beyond the selling points of pesticide dealers. Eradicating weeds from the grasslands, according to Gross, was really about controlling current threats or future outbreaks. No chemical company could honestly claim complete annihilation. Rather, eradication visions contributed to a larger failure by landowners to adapt to weeds and chemicals on their toxic terms, which often meant a set of economic and environmental consequences that threatened both the health of farmers' pocketbooks and their lands. State or local weed supervisors could help with these problems. They could give landowners the help they needed and provide an expertise that could guide the rapid transformations taking place as ever new and increasingly poisonous chemicals were being unleashed in the grasslands.

Chemical selectivity posed the greatest difficulty for most farmers. Since each noxious weed infestation was specific to the environmental characteristics of the crop under attack, the field it was occupying, and the region, landowners needed advice about the chemistry and toxicity of each herbicide. Farmers had to adapt their cultivation and production practices to the pests and their ecological behaviors. Vigilance meant doing tillage work at the proper time, understanding the general principles of both weeds and chemicals, and battling each infestation as it came about rather than waiting for weeds to become so numerous as to place fields, harvests, or livestock in jeopardy.

Gross recommended that every state in the Great Plains create a weed district, or at the very least identify the field supervisors and specialists needed to assist farmers in the chemical and biological knowledge needed to save their fields from the noxious invaders. Weed scientists were needed to oversee the programs and the policies that could prevent both infestations and chemical poisonings. The great losses, Gross insisted, that landowners had experienced in the last two decades would only increase if both the infestation rates and chemical controls were left to each individual farmer and chemical applicator. The timeliness in operations, following the lifecycles of each, specific weed, mixing and matching the correct chemical dosages, and the ability to own satisfactory spray equipment or hire reliable applicators were all keys to an effective prevention strategy. The failure of one or more of these principles, according to Gross, "has resulted in great losses to landowners because of time and material wasted, crops lost, and in many instances land badly damaged by erosion."[45] Farmers had to adapt to an emerging agricultural-chemical landscape that offered potent tools and new experts but also created a production system that encouraged new varieties of dangerous pests. Supervision, education, and selectivity offered effectiveness with a certain amount of safety, but farmers, applicators, and agriculturalists had to become more like their "unseen harvesters" and the noxious plants threatening their fields.

Gross endorsed a plan that began to move producers in the Great Plains toward a system of chemical application and weed prevention that emphasized the environmental characteristics of the region as well as the chemical components of pesticides. First, officials in each state needed to supervise all control activities. This meant that state agricultural departments needed to create a position that allowed weed scientists to have governing power in counties and communities throughout their state.

Second, weed scientists needed agricultural extension access to instruct landowners and custom operators on specific weed species, chemical varieties, and individual farmers. They also needed supervisory authority to direct the county, district, or custom operated weed control equipment. This oversight was especially desirable for aerial application, since many states and local communities had ground sprayers.

Both groups' experiences in and over fields and pastures, their interactions with noxious weeds, and studying the consequences of both forms of toxicity allowed them to adapt to the chemical properties of pesticides and articulate methods of application that reflected the region's agricultural spaces.

Third, community education had to be part of any formal plan for weed prevention in grassland agriculture. A crucial part of a weed scientist's governing duties was the ability to disseminate the economic and environmental characteristics of chemical weed control. A central duty of county or district weed men, according to Gross, was advising farmers and custom applicators on the synthetic and natural toxicity of chemicals and weeds. Selectivity and accuracy, both in mixture as well as application, would allow farmers the land fertility and productivity they were seeking; inattention and indiscriminate application was expensive and led to contamination.

Figure 4. Ted Yost (right) with J.C. Mohler, Director of the Kansas Board of Agriculture, ca. 1949. Courtesy of the Kansas Historical Society.

Figure 5. "Nebraska's weed expert, Noel S. Hanson of the University of Nebraska college of agriculture, looks at giant ragweeds that were not hit by the spray [2,4-D]. This picture was taken 10 days after the corn was sprayed." Reprinted with permission for single use from the *Nebraska Farmer*.

Fourth, a postwar noxious weed plan for the Great Plains required cooperation among producers and professionals in mapping noxious weed infestations, planning control programs, conducting demonstrations, teaching chemical toxicity, and expanding research control studies proportional to the expanding pesticide industry. This basic plan could guide farmers, custom applicators, and agriculturalists toward a more standardized and comprehensive control program but successful employment could only come if the plan was designed on the noxious characteristics of pests and the toxic characteristics of pesticides.[46]

While most attending the annual NCWCC meetings throughout the 1940s acknowledged that a uniform plan should include tests, studies, and policies that were relevant to each state, some scientists felt it did not go far enough to address the dangers of chemical application and weeds. Ross Fleetwood of the University of Missouri was outspoken about the limitations of such a plan for the Great Plains. He explained in the 1948 meeting that farm production in his state brought in such a host of noxious plants that to save infected crops or pastures meant much more local research and community involvement. "Missouri varies from a corn, hog, bindweed, Canada thistle, quackgrass set-up in North Missouri, to a cotton, Johnson grass, Bermuda grass system in Southeast Missouri." In the west, Fleetwood complained, "we are bothered with the weeds and climate of Eastern Kansas and Nebraska, while on the east we have all the weeds, vines, and shrubs which can tenacious bedevil a farmer in the Mississippi River bottoms." And in between these areas, "we have thousands of acres covered with undesirable shrubs, briars and sprouts. Within these extremes of climate and soil we find practically all the common annual, biennial and perennial weeds and grasses found in the states represented here."[47]

Fleetwood worried that in attempting to formalize standards, weed scientists would overlook the environmental and agricultural diversity of the region. "I presume that in the final analysis our situation is not too different than it is in many other states, but I'm sure we must use a different approach than is used in Iowa, Kansas and Nebraska…However, our farmers demonstrated this last year, that if we have something which works they will readily take hold of it. Therefore, I believe in all seriousness that our major problem in educational work on weed control in Missouri right now is further research information."[48]

As Fleetwood surmised, a second factor in the ability of the NCWCC to establish a comprehensive weed control plan for the Great Plains included the variability in farmer and custom applicator knowledge—both in terms of weeds and chemicals. New varieties of chemicals, weeds, and producers required a new knowledge that had to be communicated by scientists. Stories of 2,4-D effectiveness in Iowa from renowned weed scientist E.P. (Dutch) Sylwester, for example, did not convince Fleetwood that farmers in his state would find the same success because of the diversity and variability of the farmers, crops, weeds, and chemical practices. Small grains, for example, were much more sensitive to spray with the chemicals that were also used to spray pastures or brush lands. "Our row crops in Missouri are corn, soybeans, cotton and tobacco. At the present time we knew pretty well how to control broad-leaf weeds in corn but our pre-emergence spraying designed to control grasses failed to function in our season this year."[49] However, Fleetwood pointed out that these new herbicides were too potent to guarantee the safety of the land or other crops growing nearby: "soybeans are very difficult to safely spray with present chemicals and there is no practical chemical control for weeds in either cotton or tobacco. We need chemicals which will control grasses in corn and control both weeds and grasses in cotton and tobacco and probably soybeans."[50]

Although he did acknowledge that farmers, agriculturalists, and custom applicators met on a regular basis to discuss the latest chemical developments, for Fleetwood, postwar agricultural production meant understanding the tendencies of pesticides in the fields. A regional plan could not simply follow the specifications of chemical companies and the practices of farmers or custom applicators in other states; a weed plan for the grasslands had to be as dynamic as it was comprehensive. Accounting for the changes set in motion by pests and the chemicals used to control them, however, had to acknowledge that behaviors by farmers, applicators, pests, crops, and chemicals changed with their surroundings and interactions. Finally, such a plan needed to provide an instruction that could adapt and evolve with new poisons and pests every year.

Warden Noe of Kansas echoed Fleetwood's warnings. Many farmers and agriculturalists in 1948, he said, have embraced agricultural chemicals in such a way that the poisons are the new "miracle in American agriculture."[51] They view it as "a great tribute to our free enterprise system of scientific research."[52] However, to use such a "miracle," he warned, required the American methods of farming "to undergo extensive changes in operating techniques, and these changes probably will grow more pronounced within the next few years."[53] Once pesticides were unleashed on farms, pastures, and rangelands, they had the equal power to protect and to harm. These new chemicals' effectiveness also meant they were extremely dangerous.

Farmers, agriculturists, and applicators had to remember that as pesticides grew in number, variety, and potency, their poisonous tendencies in croplands, pastures, and rangelands were increasingly harmful and complex. Farm chemicals "must be treated with respect and with caution if both the greatest benefit and greatest protection is to be realized." Farmers and applicators, he said, can no longer rely on their basic chemical knowledge acquired from basic use or other farmers—"That day has passed. With the great increase in the kind and complexity of these materials it has become paramount that experts in each field be employed or made available to supply consumers, the most valuable and up to date information as possible."[54]

For Noe and many others attending the 1948 conference, chemical application went well beyond the industrial and scientific information obtained on the label. Practices, behaviors, tools, and techniques had to fit the toxic characteristics of pesticides, the lifecycles of pests, and the environmental conditions of the region. It was not enough to simply follow labels or others' application experiences. All users, whether farmers, custom applicators, or agriculturalists, needed to conform to a landscape fashioned by pesticides.[55]

The work being done by Yost, Gates, Timmons, Gross, and Larson provided a good initial framework for the region. Others such as Dutch Sylwester of Iowa State employed local education networks and field demonstrations that taught farmers and custom applicators to think like weeds and chemicals. Together these scientists, who emerged largely as a result of the postwar chemical-agricultural landscape in the Great Plains, supplied the crucial early work on the ecological relationships of weeds, crops, and chemicals. Many emphasized an application adaptability and risk assessment that was at once technological, environmental, and economical. The concerns of some NCWCC members such as James Fleetwood and Warden Noe ensured that this regional framework was nimble enough to address plant and chemical variability but could also protect farmers, sprayers, and communities from the poisonous hazards of pesticides.

Moving to the Air and Creating Toxics to Match

In 1949, F. L. Timmons assumed a new administrative role with the Bureau of Plant Industry, Soils, and Agricultural Engineering of the USDA. He attended the Eleventh Annual Western Weed Conference, in Bozeman, Montana in 1949 to describe the techniques of chemical control in the Great Plains. As a representative of the NCWCC and the Federal Government, Timmons became one of the first linkages between the regional evolution of aerial application and a larger, national chemical agricultural program that attempted to address the concerns of production and toxicity.

Timmons mainly argued chemical weed control required a host of adaptations that users needed to understand and respect. For the Great Plains, Timmons told the audience, herbicides and weeds rather than insecticides were the central forces in the development of aerial application. Although "airplanes have been used for applying insecticides and fungicides for nearly 30 years, their use for spraying weed killing chemicals is a recent development."[56] Low-volume spraying of 2,4-D was part of this rapid evolution. High in potency, cheap in cost, and low in risk, this spray formulation seemed to be the perfect answer for the grasslands. Timmons not only endorsed similar formulations for the western states, but insisted that they study the custom formulations of pesticides and the developments in aerial application in grasslands to guide polices in their region.[57]

Many weed scientists attending the NCWCC's regional meeting in Sioux Falls, South Dakota that same year heard a similar message. As Timmons was discussing aerial application with western weed scientists, regional weed men and aerial applicators were focused on how to balance the economic rewards of chemical agriculture with its risks. New toxics would continue arriving to the fields, pastures, and rangelands of the Great Plains. Landowners would convert more of their land for production, which would only expand the need for chemical protection and the dangers that came with pesticides. Farmers, scientists, and custom applicators had to conform to its patterns and characteristics or risk economic and environmental hazards to their crops, communities, and personal lives.

Learning from the noxious ones meant mixing chemicals according to the biological properties of weeds or insects, paying attention to how poisons interacted with the larger environment, how they transformed it, and the hazards of misuse. In essence, many weed scientists and custom applicators as well as a growing number of farmers realized that their production ethos had to conform, as their tools, methods, or spraying polices, to the chemicals they used. A farmland toxicity standard began to emerge that would guide the region's users toward standards, technological adaptations, and behaviors that followed the contours of the chemical-agricultural landscape.[58]

In his report on the "Motivations of Weed Control," Geo Briggs of Wisconsin argued that the growth of custom application, especially aerial spraying, needed to consider the health of farmers, and their lands had to be included in chemical weed application. Understanding how pesticides worked within the landscape—not just on it—would motivate producers toward chemical controls. Farmer skepticism toward herbicides, argued Briggs, was governed by a host of forces that often had to do as much with the untested promises of tools as it did with the pressured pitches of chemical salesmen: “I question in our form of society if there is any *one* appeal to hasten acceptance of an improved practice. A good salesman would have to use nearly every known appeal to bring about desired acceptance and perhaps at that—repetition and persistency with it.”[59]

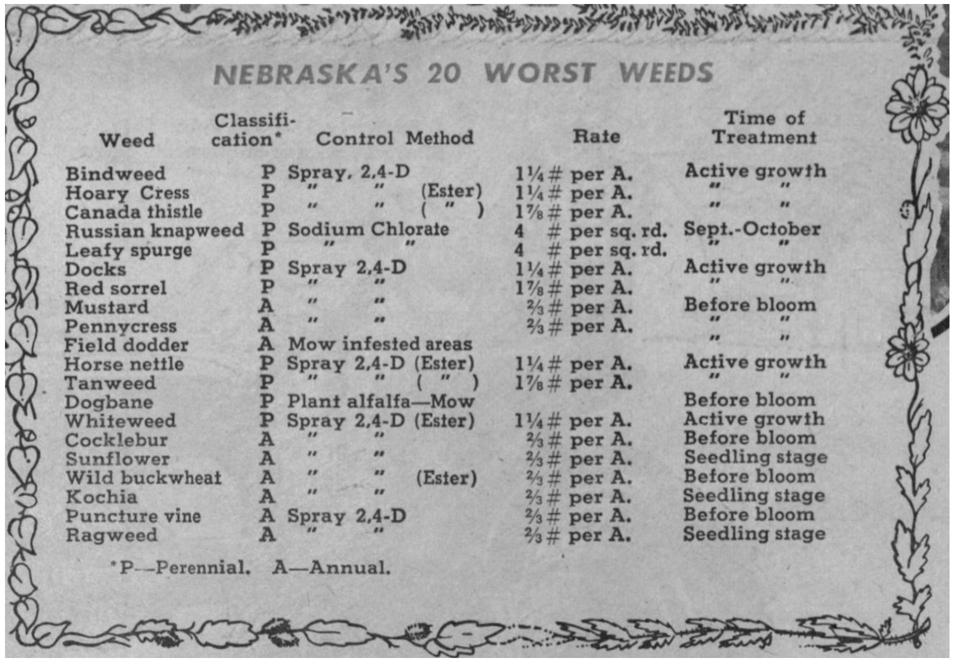
Among his eight motivational points for weed scientists and custom applicators to consider were three directly tied to farmland toxicity. Farmers had to be sure, insisted Briggs, that the new, potent herbicides and the custom applicators spraying them did not endanger their health or their community’s health. “The appeal of human health,” he insisted, is related to the toxic effects of noxious plants as well as the chemicals meant to control them. “Few practices are often subscribed to without fully knowing the after effects and all the implications. I don’t know of any new practice for weed control that has fewer objections than the new weed control procedure when used according to the standard methods. Its effect on human health, on plant life, and on equipment is all to be recognized with, but when understood, has fewer hazards than most farm practices.”[60]

Agricultural chemicals, according to Briggs, were indeed dangerous, but careful application practices, knowing the hazards, and identifying the safety measures increased the likelihood that landowners would accept this technology as they had had earlier tools: “we could make long lists of common practices of farmers that all have hazards but knowing the problem, farmers soon accept them and avoid injury when following safety measures.”[61] Finally, Briggs insisted that community support was crucial to overcoming farmers’ skepticism. Healthy fields where weeds were controlled and healthy communities protected from chemical poisons began with the local agricultural community. He observed, "believe it or not we are influenced by what our neighbors are doing. That is why mass action is brought about by mass appeal. When neighbors all give consideration to a united front, it's surprising how easy it is for others to follow. The importance then is someone seeing that all are properly informed, and where some are not willing to cooperate, the legal provisions will be exercised and the importance of others knowing that the provision will be enforced."[62]

Noxious plants' and insects' ability to harm through root strangulation, sneaking nutrients from useful crops, or smothering them by growing faster than corn or wheat placed a selective few in the crosshairs of farmers, weed experts, and chemical applicators. Each worked together to find herbicides that were selective enough to kill the noxious plants but safe enough to keep their soils and crops from long-term damage. Agricultural newspapers such as the *Nebraska Farmer, Kansas Farmer,* and *Wallace Farmer* outlined their most-wanted weeds and the basic mixture-ratios to match them. These helped farmers to identity each weed, its growing cycle (annual or perennial), recommended chemical control method, which was almost exclusively the herbicide 2,4-D, calculated the rate of application, and estimated the time of treatment. Landowners were encouraged to match these suggestions with the labels or the application literature obtained from experiment stations or local weed scientists. However, it was often farmers or applicators themselves who constructed methods and mixtures that, they felt, best suited the conditions of their fields.[63]

For aerial applicators, as for many farmers, a simple mixture guide on the cover of an agricultural periodical was not enough. Similar to how landowners adapted their chemicals to what was attacking their fields, pilots had to adapt their planes and sprays to the environmental characteristics of the region, pest, and farm space. This evolutionary transformation, according to L.L. Coulter, meant aerial sprayers needed to remain vigilant of the nature of these chemicals as well as that of pests that went beyond basic labels, agricultural reports, or farmers' testimonials.

Speaking particularly about the various formulations of 2,4-D, Coulter argued in his paper "From Test Tube to Aerial Operator" that if pilots employed this kind of analysis in their application process, chemical companies would have no choice but to provide lower volume herbicides with higher solubility and grater selectivity. "Any chemical generally goes through a series of steps in the transition 'from test tube to the airplane operator.' Materials are tested and screened…in the laboratory. Those which show promise are referred to chemists for formulation."[64] However, selling "something that should work," Coulter surmised, could be as hazardous to the land, crops, and farm communities as its purported potential. "Aerial application of herbicides is not a barnstorming proposition; it is a science requiring that the operator be as well grounded as possible in the technical aspects of the problem which he is undertaking to control."[65] Aerial sprayers must, Coulter maintained, "consult with local agricultural authorities or with fieldmen of reliable commercial companies who are known to have carried out research on the problem with which he is concerned. It can not be over emphasized that success in aerial weed control depends on the sound application of the results from field testing by well informed pilots."[66]



NEBRASKA'S 20 WORST WEEDS

Weed	Classification*	Control Method	Rate	Time of Treatment
Bindweed	P	Spray, 2,4-D	1¼ # per A.	Active growth
Hoary Cress	P	" " (Ester)	1¼ # per A.	" "
Canada thistle	P	" " (")	1⅞ # per A.	" "
Russian knapweed	P	Sodium Chlorate	4 # per sq. rd.	Sept.-October
Leafy spurge	P	" "	4 # per sq. rd.	" "
Docks	P	Spray 2,4-D	1¼ # per A.	Active growth
Red sorrel	P	" "	1⅞ # per A.	" "
Mustard	A	" "	⅔ # per A.	Before bloom
Pennycress	A	" "	⅔ # per A.	" "
Field dodder	A	Mow infested areas		" "
Horse nettle	P	Spray 2,4-D (Ester)	1¼ # per A.	Active growth
Tanweed	P	" " (")	1⅞ # per A.	" "
Dogbane	P	Plant alfalfa—Mow		Before bloom
Whiteweed	P	Spray 2,4-D (Ester)	1¼ # per A.	Active growth
Cocklebur	A	" "	⅔ # per A.	Before bloom
Sunflower	A	" "	⅔ # per A.	Seedling stage
Wild buckwheat	A	" " (Ester)	⅔ # per A.	Before bloom
Kochia	A	" "	⅔ # per A.	Seedling stage
Puncture vine	A	Spray 2,4-D	⅔ # per A.	Before bloom
Ragweed	A	" "	⅔ # per A.	Seedling stage

*P—Perennial. A—Annual.

Figure 6. Here is an early version of Nebraska's noxious weed most wanted list according to the *Nebraska Farmer* in 1947. Also included are the herbicide application instructions for each—classification, control method, and time of treatment. Reprinted with permission from the *Nebraska Farmer* for single use.

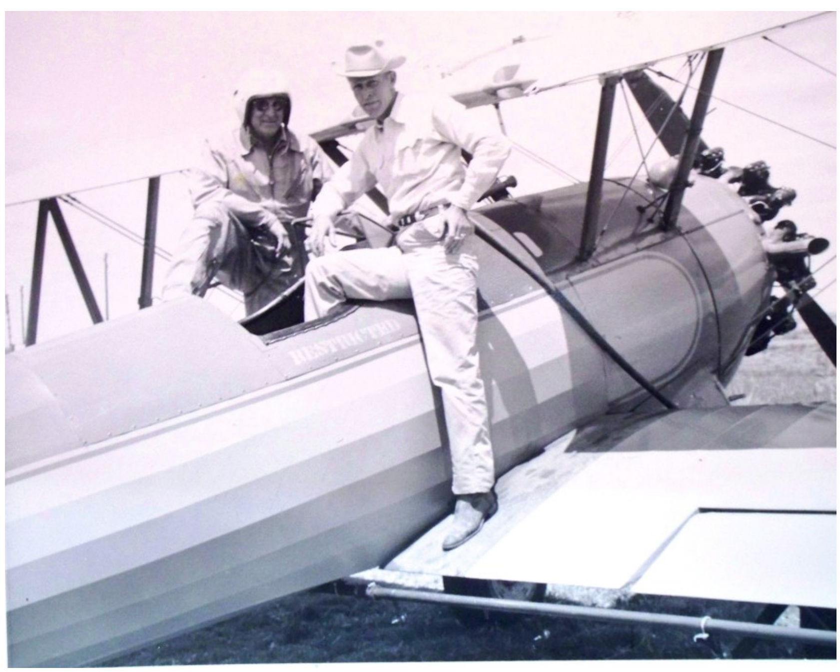


Figure 7. Kansas Ag Pilot Roy Mahon consulting with a Weed Scientist, ca. 1949. Courtesy of the Kansas Historical Society.

These types of environmental, technological, and biological factors associated with chemical agriculture defined the development of aerial application, quickly making it a central tool in chemical farming of the Great Plains. Both pesticides and pests followed their own logic according to their species and synthetic construction. New varieties of farmer, custom applicator, and agriculturalist appeared as pesticides were increasingly being sprayed from the air, absorbed in the ground, and poisoning pests. Thinking like weeds, insects, and chemicals in the grasslands meant adapting mixtures, machines, and attitudes to fit their toxic tendencies rather than simply believing that if some pesticides worked, then more must be better. So much of spraying the airplane way related to these regional relationships and the chemical-agricultural landscape that pesticides helped construct. While these new types of producer, scientist, and aerial sprayer were pushed by cultural memes of war and the growing production requirements of the land, aerial application also embodied the traits of pests, poisons, and the region.

Notes

[1] L.W. Kephart and S.W. Griffin, "Chemical Weed Killers After the War," in *Proceedings* (Omaha, Nebraska: November 16 and 17, 1944),78.

[2] "Knowing Agricultural Chemicals" *Air Applicator Informational Series, Volume 1* (Agricultural Aviation Academy: Douglas County Airport, Minden, Nevada: 1965), 40.

[3] For Field Bindweed (Convolvulus arvenisis L.) see H.F. Roberts, "Principal Noxious Weeds of Kansas," *Agricultural Experiment Station Circular 84* (Manhattan, KS: Kansas State Agricultural College, October, 1920), 1–9; "Noxious Weed Strangles Kansas Crops," Kansas State University News Release, March 17, 1994, 1–2; For Musk Thistle (Carduus nutans L.) see Ronald McGregor, *Musk Thistle in Kansas: Observations from 1940–1985*, No. 14 (Lawrence: University of Kansas Herbarium, 1985); Freeman E. Biery, "Musk Thistle Threatens," *Forty-Eight Annual Report* (Topeka: Kansas Board of Agriculture, 1964-1965), 120–123. For Johnson Grass see Biery, "The Johnson Grass Problem," *Forty-ninth Annual Report* (Topeka: Kansas Board of Agriculture), 116–118; For Locoweed and Death Camas see Harold S. Choguill, "Some Poisonous Plants of Kansas," *Transactions of the Kansas Academy of Science* 61.1 (Spring 1958), For a larger survey of these weeds in the Great Plains see B. H. Grigsby, "Recommendations of Research Committee of NCWCC for 1950," *Proceedings* (Sioux Falls, South Dakota: December 6–8,1949), 107–108. Also see, Duane Isely, *Weed Identification and Control In the North Central States* (Ames, Iowa State University Press, 1960); "Nebraska Weeds," *Bulletin No. 101-R* (Lincoln: Nebraska Department of Agriculture and Inspection, August 1962); James Stubbendieck, Geir Y. Friisoe, and Margaret R. Bolick, *Weeds of Nebraska and the Great Plains* (Lincoln: Nebraska Department of Agriculture, 1994, 1995).

[4] O. I. Berge, "Multiple Use of Farm Spraying Equipment," *Proceedings*, (1950), 71–73.

[5] As Everett T. Winter commented at the 1948 North Central Weed Control Conference: "It's fun to kid our scientists as we have done here tonight, but I know and I sincerely believe that…your basic philosophy is the same as that of my Kansas farmer friend, to whom I referred a minute ago. This is what he said— God gave us the land to tend not to spend. He gave it to us to cultivate, to preserve, to use, to live upon. He gave it to us to furnish us with food and clothing and what else we need to live happily and comfortably. Good land is the basis of our civilization. It is God's gift to man, and it's our sacred duty to protect and to preserve it and to pass it on to future generations so that they too may fully enjoy the benefits and opportunities which we have inherited (108). See Everett T. Winter, "A Broad Look At Future Agriculture in the North Central Area," in the *Proceedings* (Topeka, Kansas: December 10–12, 1947), 108.

[6] "Gangsters in the Grass," in the *Nebraska Farmer*, 5 April 1947, 9.

[7] Ibid.

[8] Ibid.

[9] Noel Hanson, "Past, Present, and Future in the North Central Weed Control Conference," *Proceedings* (Topeka, Kansas: December 10–12, 1947), 12.

[10] Ibid., 9.

[11] A.H. Larson, "Habits and Characteristics of Weeds," *Proceedings* (Omaha, Nebraska: November 16 and 17, 1944), 66.

[12] Ibid.

[13] Ibid.

[14] Ibid., 67.

[15] Ibid., 67.

[16] Ibid; Also see Robert T. Coupland, "Life History Studies of Weeds," *Proceedings* (Winnipeg, Canada: December 9–11, 1952), 35–38.

[17] Ibid.

[18] Isley, *Weed Identification and Control*; Also see, A.L. Bakke, "Competitive Cropping," in *Proceedings* (Omaha, Nebraska: November 16–17, 1944), 98–99; DuPont "This is Du Pont: The Story of Farm Chemicals," (E.I. DuPont De Nemours & Company, Wilmington, Delaware, 1953), 20–21, courtesy of the Donald and Mildred Othmer Library, The Chemical Heritage Foundation, Philadelphia, Pennsylvania. Also see Joe Anderson's *Industrializing the Corn Belt*, 33–50. Anderson describes how Iowa State weed scientist E.P. "Dutch" Sylwester collaborated with Iowa extension drama specialist Pearl Converse to write a melodrama that caricatured weeds, herbicide 2, 4-D, and farmers. As Anderson suggests, the skit is undated but probably occurred sometime between 1945 and 1947. A copy of the skit can be found on Iowa State University extension weed management specialist, Dr. Bob Hartzler's website: http://www.weeds.iastate.edu/weednews/24dplay.htm

[19] Dayton L. Klingman and M. K. McCarty, *Interrelations of Methods of Weed Control and Pasture Management at Lincoln, Nebraska, 1949–1955* (Washington D.C., GPO: April 1958), 1–47.

[20] Ibid.

[21] Wilfred W. Robbins, Alden S. Crafts, and Richard N. Raynor, *Weed Control: A Textbook and Manual* (New York and London, McGraw-Hill Book Company, 1942), 385–390.

[22] *Industrialist*, 30 September 1931. The *Industrialist* was a campus newspaper of Kansas State Agricultural College. It reported that "Dr. Frank c. Gates, who is one of the more prolific writers among the scientific staff of the college, recently has published a Kansas agricultural experiment station bulletin 'Principal Poisonous Plants of Kansas' (Technical Bulletin No. 25). This is the only state experiment station bulletin on the subject." Also see "Frank C. Gates" in the Faculty File Records, Morse Department of Special Collections at Kansas State University, Manhattan, Kansas.

[23] Frank C. Gates, "Weeds In Kansas," *Report of the Kansas State Board of Agriculture* (Topeka: Kansas State Printing Plant, June 1941), 14–15.

[24] Ibid.: "The seeds of some weeds are equipped with special devices such as claws, beards, barbs or spines, which may become attached to animals, birds, persons or machinery, and carried considerable distances. Other seeds have special facilities for distribution by air or by water, and the tumble weeds have their own natural means of spreading seed (15)."

[25] Ibid., 22.

[26] Ibid., 68.

[27] Ibid.

[28] Ibid.

[29] Ronald L. McGregor, "Musk Thistle in Kansas: Observations From 1940-1985," *Contributions from the University of Kansas Herbarium, No. 14*, Ralph E. Brooks, ed. (Lawrence: University Press of Kansas, 1985), 1.

[30] Ibid.

[31] Ibid.

[32] F. L. Timmons insisted, for instance, that many scientists, farmers, and custom applicators throughout the region extensively used 2,4-D and other kinds of herbicides because weeds created both a threat for producers as well as a micro-environment for insects and disease. Also, herbicides were more palatable to sprays rather than dust form, which was safer and more for aerial application. These factors, as this chapter argues, contributed to the evolution of aerial spraying of farm chemicals. See F. L. Timmons, "Airplane Application of Herbicides," in the *Proceedings of the 11th Annual Western Weed Conference* (Bozeman, Montana: February 2–4, 1949), 35–39; Oral History Video Interview with Kansas Spray Pilots, by the Kansas Agricultural Aviation Association, unpublished, author's personal collection (KAAA Conference, Hutchinson, KS: precise date unknown, c. 1990s).

[33] T. F. Yost, "Presidential Address," *Proceedings* (St. Paul, Minnesota: November 26–28, 1945), 8. At the end of his introductory speech, Yost insisted that every representative and attendee join him in using the NCWC as an organization that achieves committee and member action in each state. "In closing, may I say that the value of this organization, like others, lies in its ability to achieve at least some of the purposes for which it was set up. Our principal hope of achievement lies in committee action. To serve on a committee is real work if something worth while is going to be achieved. Every member in the Conference should have an assignment so he can assist in building a stronger more effective and worth while organization to the end that the Federal Department of Agriculture will have a strong weed office set up to cooperate with the various stats in research, education and control, and that each state will have a sound and effective law and program to cope with their weed problems (8)."

[34] F. L. Timmons, "A History of Weed Control in the United States and Canada," *Weed Science* 53 (November-December 2005): 748–761.

[35] The plant was so dangerous, in fact, that Congress appropriated 40,000 dollars to answer the growing demand of landowners throughout the Great Plains and western states to find a viable control solution.

[36] Ibid., Timmons, "A History of Weed Control," 753.

[37] Ibid.

[38] Ibid., Timmons, "History of Weed Control," 755.

[39] Ibid.

[40] C. H. Schrader, "Purpose of the Weed Conference," *Proceedings* (Omaha, Nebraska: November 16 and 17, 1944), 10.

[41] Ibid.

[42] Ibid.

[43] Ibid., Yost, "Presidential Address," 8.

[44] Ibid.,17.

[45] D. L. Gross, "Post-War Weed Program Committee Report," *Proceedings* (Omaha, Nebraska: November 16–17, 1944), 124–132.

[46] Gross insisted that the educational phase of the noxious weed plan was perhaps most crucial to protecting the grasslands against the toxic attributes of weeds and chemical misapplication. The grasslands were a

sensitive landscape and they had to be protected in kind. Thus, facilitating action had to come from meeting the farmer, custom applicator, and other agriculturalists in a local context that included the socio-economic aspects of Great Plains as well as the environmental and chemical attributes of the chemical-agricultural landscape: "Facilitating action may not be strictly classified as education, yet it must be an integral part of it. if our efforts along the education line are to be fruitful, no educational program, the purpose of which is to stimulate action can be successful without first removing impediments to action…. There is no more effective educational method of including action, than the holding of field meetings where certain method of procedures are demonstrated. As many of these as possible need to be held or established. These might include the manner of spreading or spraying chemicals, or the effect these have on the weeds…. (126). Also see F. L. Timmons' discussion "The Value of Past Weed Research to the Agricultural Progress of the Region" (127–132). Serving on the same postwar panel with Gross, Timmons' identified the problems and concerns of both weed and chemical toxicity by surveying earlier application methods. Timmons outlines seventeen points that "a considerable number of state experiment stations and the Bureau of Plant Industry" were practicing throughout the 1930s and interwar period (128). Point 12, for example, described the "testing of a large number of herbicides including proprietary chemicals to determine their relative efficiency in weed control or eradication (128)." In Point 14, Timmons identifies that agriculturalists also determined the "optimum dates, rates, and methods for applying the various herbicides to different weeds in different sections of the country under various conditions of soil and climate (128)." Finally, in Point 15, Timmons reminds the panel and audience that fire remains a viable alternative to "controlling annual and perennial weeds (128)."

[47] Ross Fleetwood, "Educational Problems of Weed Control in Missouri," *Proceedings* (Springfield, Illinois: December 8–10, 1948), 205.

[48] Ibid.

[49] Ibid.

[50] Ibid.

[51] Warden Noe, "What Do We Need in Herbicide Laws?" *Proceedings* (Springfield, Illinois: December 8–10, 1948), 143.

[52] Ibid.

[53] Ibid.

[54] Ibid.

[55] Ibid. Also see K.S. Quisenberry, "Weed Control in the Agricultural Research Meeting," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 92–95. In his presentation on the current postwar status of weed control in the region's agricultural research program, Quisenberry feared that producers were not doing enough to curb the potential folly associated weeds and chemicals. He stressed that cultural practices still had a place in the new chemical-agricultural landscape. "One almost might conclude," he said, "that cultural practices have failed completely, yet we know this is not so." Herbicides have rendered amazing results, "but we must not forget that proper cultural practices, crop rotations, sols, and range management, are basic requirement sin most effective weed control." There is nothing new, insisted Quisenberry, "about this viewpoint of course, but to me it seems important yet easily forgotten. In a well-balanced program all possible methods of control must be and are being considered (92)."

[56] F. L. Timmons, "Airplane Application of Herbicides," in the *Proceedings of the 11th Annual Western Weed Conference* (Bozeman, Montana: February 2–4, 1949), 35–39.

[57] Ibid; E. H. McIlvain and D. A. Savage, "Spraying 2, 4-D by Airplane on Sand Sagebrush and Other Plants of the Southern Great Plains," *Journal of Range Management* 2 (April 1949): 43–52.

[58] W.E. Loomis, "Basic Research in Weed Control," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 101–103. In his study, Loomis describes four stages in herbicide formulation to match the specific weed species. First farmers or custom applicators needed to research *coverage*. This stage included studying the "volume and dosage of pressures and nozzle types, of surface tension and of evaporation rates. The process of translocation or the ability of the chemical to move away or reside in surrounding plants and soil is an important consideration of this stage. Second, farmers and applicators needed to understand chemical *penetration*. As Loomis suggests, "the more rapid action of low-surface-tension sprays can be shown to be due to more rapid penetration…. In young or rapidly growing plants and cuticle and cellulose layers are thin and permeable and the membrane is relatively unstable. Such leaves are rather easily penetrated (101)." However, "older plants, particularly in dry weather or on poor soil, accumulate sugars and other carbohydrates which they are unable to use in growth. Higher sugars stimulate differentiation or hardening, in which the cuticle is thickened and may form a continuous layer; the cellulose wall is thickened and perhaps partly impregnated with wax; and the entire cytoplasm as well as the membrane is toughened so that it resists both the penetration and toxic action of 2,4-D (101)." The third stage is *translocation*. To guard against the toxic expansion of pesticides into the soil or surrounding crops or pastures, Loomis suggests that smaller, more selective dosages be used. Fourth, a better understanding of *toxicity* would allow farmers and applicators to improve effectiveness while at the same guard against injury or hazard (102-103).

[59] Geo M. Briggs, "Motivations of Weed Control," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 27–28.

[60] Ibid.

[61] Ibid.

[62] Ibid; Also see, "How Farm People Accept new Ideas," *Special Report No. 15*, Iowa State College, Ames 1955 and Joe M. Bohlen, "Adoption and Diffusion of Ideas in Agriculture," in *Our Changing Rural Society*, ed., James H. Copp (Ames: Iowa State University Press, 1964).

[63] L. L. Coulter, "From Test Tube to Airplane Operators," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 42; Joe M. Bohlen and George M. Beal, and Daryl Hobbs, "The Iowa Farmer and Farm Chemicals: Attitudes, Level of Knowledge, and Patterns of Use" *Rural Sociology Report No. 3* (Department of Economics and Sociology, Iowa State University: November 1958). Also see Anderson, *Industrializing the Corn Belt*, 8–10; 17–32.

[64] Coulter, "From Test Tube to Airplane Operators," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 42; Dale E. Wolf and A. L. Flenner, "Herbicidal Formulations," *Proceedings* (Milwaukee, Wisconsin: December 12–14, 1950), 22–24.

[65] Ibid., Coulter.

[66] Ibid; E. H. McIlvain and D. A. Savage, "Spraying 2, 4-D by Airplane on Sand Sagebrush and Other Plants of the Southern Great Plains," *Journal of Range Management* 2 (April 1949): 43–52.

Chapter 3: Spraying the Airplane Way

It's a chill, gray 4 a.m. somewhere in Minnesota or Mississippi, California or Kentucky, or the Carolinas. Far out on a lonely crossroads airstrip, a sleepy pilot shivers and adjusts his crash helmet, goggles, and respirator while ground crewmen fill his spray plane's tank and pesticide. They finish the job. The pilot pulls on his gloves and climbs into the cockpit. A moment later, the plane wheels slowly out and faces down the runway in the cool, still air of the breaking day. Now the motor roars. The plane speeds down the runway faster and faster. The tail lifts. Wheels spin free as at the last the plane pulls up from the ground and heads off in the direction of the spreading green checkerboard of fields it's scheduled to treat. This is Operation Sprayday. A farmer is fighting insects that threaten his crops. He is spraying the aircraft way. [1]

*Excerpt from "*Operation Sprayday.*"*

We're the lowest flying guys in the world. [2]

Chuck A. LeMaster, Ag Pilot, Ottawa, Kansas

The spray plane's expansion in the postwar era was influenced by wartime applications and attitudes. As historian Edmund Russell has argued, many Americans "welcomed technology that brought 'total victory' over national and natural enemies. They felt grateful for a bomb that saved the lives of American soldiers and for chemical[s] that enabled people to 'bomb' insect pests."[3] This was certainly true in the Ag plane's development. Aerial spraying or "agricultural aviation" also highlighted the scientific reductionism and economic efficiency of postwar agriculture. Controlling insects and weeds was the first step toward healthier yields and larger landholdings. By reducing farm labor and insect infestations at the same time, farmers could increase their economies of scale.[4]

The spray plane and its agricultural applications were also products of the chemical-agricultural landscape that appeared throughout the region after the war. Local conditions, weeds, insects, and chemical toxicity all shaped airplane design, its effectiveness, and popularity among landowners. Spraying crops required pilots who understood chemical, environmental, and aerial risks. Ag pilots needed a working knowledge of these factors before they entered the sky and they required planes that accurately dispersed chemicals.

The development of aerial application in the postwar era, then, was not just a consequence of postwar agricultural production policies or the residue of American wartime efforts but a technological manifestation of how pesticides followed their own logic within the region. The problems of chemical toxicity, the ecological lives of weeds, insects, and crop disease, and the meteorological, climatic, and geological conditions of the grasslands all forced pilots and farmers to modify not only the way they farmed or flew but their attitudes about chemical effectiveness and environmental risk. Indeed, the technological prototypes, user-based controls, and various spraying techniques implemented by pilots were as much a result of the intersections between fields, crops, pests as they were the consequence of war or the influence of postwar agricultural production.

From Cotton Fields to Grasslands: The Regional Origins of Aerial Application

The use of aircraft in agriculture began in the cotton fields of the South where planters wanted to gain a new aerial edge in a very old fight. Cotton farmers, in particular, had long desired to conquer the boll weevil. The insect arrived in the South in the 1890s and continued infesting fields throughout the early 1900s. The first signs of a weevil attack came from punctures in the cotton plant squares, opening the plant for female weevils to lay eggs inside, which kept them safe and healthy. As the eggs hatched, the larvae feasted on cotton fibers until they killed the square entirely. When these weevils reached adulthood they expanded their communities and repeated their lifecycles over and over again.[5] As historian James Giesen has shown, farmers in the South ultimately had two choices: they could fear the onset of infestation and attempt its control or dramatically rethink the ways they farmed and their attitudes toward the land. Adaptation of agricultural practices, not just insect control methods, had to accompany farmers' battles against the weevil. The only way to save southern agriculture was through practical solutions that, as Giesen put it, "led to better cotton farming and less cotton farming."[6]

As war broke out in Europe, farmers saw cotton prices plummet. The disruption of shipping routes and international demand meant planters could no longer produce cotton at a profit. This dramatic drop in price convinced some to transition into other crops such as peanuts, but most farmers remained faithful to king cotton, betting that prices would turn around to usher in new era of prosperity. Prices did rise eventually, but so did the intensity of infestations.[7] By 1921, many southern states had reached a crisis point. In Texas, for example, most if not all community/government control efforts had largely failed. As the *New York Times* reported, "the little pirate was almost at the top line of the cotton zone, and apparently had the conquest of the former king of our commerce nearly in his grasp."[8] Millions had been spent, according to the paper, "to hold him back, only to face failure year after year."[9] An aerial edge seemed the only way to beat their insect foes. A birds-eye view of weevil attacks provided the necessary reconnaissance for effective ground-spraying and rapid chemical application.[10]

There were plenty of reasons for experts and farmers to embrace the airplane as a farm implement. The aeronautical advancements that emerged from World War I demonstrated a new ability to protect farmers' lands. Landowners could survey their fields for pests, check up on their livestock, or transport supplies from one place to another. As infestations hit southern farms in the years after the war, authorities began to explore ways to incorporate aircraft into cotton agriculture for the expressed purpose of controlling pests.

Texas provided one of the first case studies. In 1919, cotton planters experienced a double threat to their fields. Boll weevil mania was alive and well throughout the state but farmers also worried about the pink bollworm. The first alarm was issued by federal authorities four years earlier in 1915 when farmers discovered small infestations around Trinity Bay, Beaumont, and Hearne, Texas. State and federal authorities both developed an import restriction plan that required all cotton materials and seeds to be fumigated upon entry. A year later, however, planters reported multiple infestations and feared that their inability to control both pests would destroy Texas's crops while threatening other cotton states. Pink bollworms destroyed cotton by burrowing into the boll, eating all of the plant's seeds, and then exiting the boll after 10 to 14 days as moths. The worms reduced not only the quality and quantity of current cotton yields but also the larvae that developed late in the season, which had the potential to pass the winter by living in old bolls or even cracks in the soil.[11] Mobility was the main problem. As the USDA's *Weekly News Letter* reported in 1919, landowners and officials throughout the South feared that the insects had an easy route into other cotton states. It reported, "the chief agent of dissemination being man with his railroad trains, the distance from Texas to Georgia or

North Carolina is no great jump—and it probably would not be a direct jump."[12] Officials in the Texas State Department and USDA, according to the report, also blamed the 1915 Galveston Hurricane for the infestations: "the great storm that ravaged the Gulf country in 1915 washed ashore around Trinity Bay and possibly elsewhere on the Texas coast great quantities of cotton lint and cotton seed. Nobody gave any special thought to the matter at the moment, but when the next year the pink bollworm appeared all around the bay the next year, it became apparent that some of the washed-up cotton must have come across the Gulf from the Laguna district of Mexico, where the pink bollworm had gained a footing some time earlier."[13] The dangers of a combined weevil and worm infestation produced an agricultural emergency that required aerial surveillance and spraying.

Texas authorities were already using aircraft to regulate cotton quarantine zones. Theoretically, these sections would contain weevils and worms while at the same time limit overall cotton production. Through reduction and quarantine, officials in the Texas State Department of Agriculture believed they could find new ways of controlling them and bolster cotton prices.

Some planters, however, had different plans. Quarantine zones, to them, meant dangerous government intrusion—a danger, they believed, to be equal to that of weevils and worms. These "outlaw" farmers refused to follow zone restrictions and continued to harvest quarantine cotton against growing warnings by agricultural leaders and state officials. To escape detection, landowners also planted cotton in areas that were difficult for officials to access. They explored sections of the cotton-free zones heavily timbered and far away from the main roads. Finally, planters mixed their outlaw cotton with their healthy yields in an effort to confuse inspectors.[14] Aerial surveys, in many ways, were the only method available to officials. If growers stuck only to ground rigs, weevils, worms, and outlaw planters enjoyed the advantage. Aerial surveillance, on the other hand, gave officials the advantage. They could watch over the cotton-free zones, report to law-abiding farmers about the status of their crops, and begin to map county lands for future agricultural production. Yet, planters and officials wanted more. Aerial chemical application, in their minds, offered the kind of protection and economic benefit that would save their lands from infestations and perhaps their cotton fortunes.

Texan officials turned to the US Army. Lieutenant Harold Compere, son of the world renowned entomologist George Compere, to oversee future quarantine survey operations and begin to explore the possibility of aerial chemical applications. Compere was originally stationed at Ellington Airfield outside of Houston with the Division of Military Aeronautics, but state officials asked him to pilot these emergency survey missions after two other aviators, Lieutentant William H. Tillisch (army aviator) and E.L. Diven (Texas Department of Agriculture aerial observer) suddenly died while flying over cotton-free zones in southern Texas. While continuing to investigate fields for outlaw farmers and insects, Compere realized that an airplane's agricultural value directly related to the pilot's knowledge of aeronautics, region, crop, and pest. Airplanes were only a valuable tool to the farmer, he insisted, if pilots were trained as scientists as well as aviators.[15]

Compere's work in Texas underscores the early transformation of the airplane from a wartime technology to an agricultural tool as well as a prelude to the chemurgic influence on farmers in the 1930s. His aerial scouting missions represented the first step toward chemical conversion because in the attempt to save fields and control pests, officials and planters alike began to link the advantages of aerial surveillance with crop and pest control. Compere's contribution moved this transition forward by asserting that pilots needed a scientific and regional knowledge, not just aeronautical ability, to effectively combat infestation and ensure crop health. The first instance of dusting came a few years later when Ohio farmers demanded an aerial solution for an insect outbreak of their own. The sphinx caterpillar had arrived in Ohio's fields, and communities and landowners worried, much like southern planters, that crops would die and yields would wilt away.[16]

"Only Birds Could Get the Stuff Up There"

Similar to the decision Texas officials made to begin using aircraft in locating outlaw cotton fields and insects, Ohio farmers such as Harry Carver demanded technological answers for insect threats against their fields. Carver primarily farmed Catalpa trees which were popular lawn-shade trees of the period. His struggles with the sphinx caterpillar that fed on the Catalpa's leaves came to head in 1921 when an infestation could not be stopped with regular ground spraying equipment. Regardless of individual spray-machine or ground rig, these trees lost all of their leafage. Carver pleaded with city and state officials to develop a method of chemical application that began at the top of his trees rather than from the ground. Carver's idea caught the attention of city entomologist C.R. Neillie, who was working on an application plan that could protect city parks from the insect. Even the most advanced ground sprayer of the period failed to deliver the dusts high enough for effective worm control. An airplane, Neillie believed, solved both problems. It allowed officials to survey tree damage as well as get the insecticides high enough to protect the trees—a spraying feat that Neillie jokingly recommended could also be done by employing the local bird population.[17]

Both men enlisted the help of Ohio agriculturalists, university engineers, and the United States Army Air Service to organize an experimental test flight at McCook Airfield in 1921, which was near Carver's fields. Ohio Agricultural Experiment Station entomologist J. S. Houser accompanied Neillie in converting an old World War I trainer plane, the Curtiss JN-6 (known by aviators as the Curtiss Jenny), into a duster by designing a crude hopper on the right side of the fuselage just under the passenger cockpit. The men also constructed a slide door that moved back and forth, creating a partial vacuum for dust dispersal. At the top of the hopper, Neillie and Houser installed a hand-crank that connected to a bladed mechanism that mixed the lead arsenate dust. Overall, the entomologists boasted, this dusting prototype could hold approximately thirty-two gallons of dust or spray for any insect attack.[18]

Late in the summer of 1921, Lieutenant John Macrady and his engineering assistant, E. Dormoy, took the experimental aircraft on its first chemical flight to combat the sphinx caterpillar. With Macrady piloting the sprayer and Dormoy cranking the mixer and monitoring the hopper, the duster team made six passes over Carver's catalpa trees, dusting them with a mixture of lead arsenate. Flying at about 80 miles per hour, the Ohio men went directly into the wind hoping to extend their chemical swath as far as possible. Macrady and Dormoy sprayed a total of two full loads of lead arsenate powder that day and its toxic effects, according to observers on the ground, were almost immediate. Carver observed that almost 99 percent of the pests had been destroyed, and "thousands and thousands of dead caterpillars [were] hanging from the leaves and on the trees and ground."[19] The official story was a success. Caterpillars died and fields were saved in record time. Neillie and other officials argued that the fears by some eyewitnesses that "poison dust was being tossed willy nilly" were unfounded and any risks were minimal compared to the advantages of one pilot accomplishing in a few minutes what would normally take days and a number of ground sprayers to do.[20]

The Ohio duster success story quickly spread throughout the South and Great Plains. By the 1930s, officials in places like the Mississippi Delta, for example not only embraced aerial spraying as a potential method in cotton cultivation, but also endorsed it as a main agricultural practice. Planters and officials increasingly embodied a belief that if a little worked, more must be better. Even if pilots sprayed heavy dosages without paying much attention to field boundaries or where the dusts actually landed, many farmers and agricultural policymakers believed that if they could rid their crops of pests, chemicals could drift wherever they liked.

Throughout the 1930s and 1940s, however, landowners in the Plains states held different views about spraying chemicals from the sky. They worried that pilots would destroy more than they saved, making aerial application a dangerous solution, only to be used as a last resort to protect their fields, pastures, or rangelands. In Texas, not all cotton planters in the state agreed with indiscriminate spraying of cotton fields. Farmers such as Holland Porter in Bryan, Texas remembered that many landowners were conflicted about aerial application, only calling Ag pilots if they feared a looming insect attack. Hiring an aerial dusting company to come in and spray their crops, according to Porter, was a farmer's last-ditch effort to save his fields.

In Porter's case, an attack of armyworms (another caterpillar pest similar to bollworms) in 1929 left him and other landowners helpless. He recalled, "we had burned nearly every mule and horse on the farm and broken all of the chains in the country on the old poison machines, but the leaf worms still ate us up. We were using calcium arsenate and adding Paris Green ourselves by stirring it in and rolling it around in a barrel. There was nothing wrong with the poison; we just weren't getting it on fast enough or in an even distribution."[21]

Along with Porter, many other experts and growers realized that while airplane dusting treated fields quickly, pilots had trouble keeping their sprays from drifting into other fields. They were flying planes with minimal maneuverability, and avoiding the numerous obstacles on or near fields such as fence posts, pecan trees, and tenant houses were an exceptional challenge. Also, pilots were often unprofessional, according to Porter, with little supervision or standardization: "pilots were pretty wild…both on the ground and in the air, but they could do lots of things with those old planes and when they were not flying they were either working on them or off doing a little drinking."[22]

Farmers had a right to be concerned. Many spray planes, in these early years, were crude collections of parts and equipment. Applicators seemed to be closer to stunt pilots than citizen scientists. In response, landowners only hired pilots that were also farmers with the idea that if applicators owned land themselves, they would most likely have a better understanding of the agricultural relationships at risk.[23] In 1934, Porter decided to start his own spraying business by advertising his agricultural knowledge and application abilities. A successful pilot, according to Porter, needed a local knowledge of the region—its environmental conditions, crop vulnerabilities, and the types of chemicals needed to adequately protect a farmer's fields—as well as flying expertise.

In this way, applicators had to maintain strong relationships with landowners, agricultural experts, and rural communities. Aeronautical or chemical mistakes not only destroyed fields or contaminated soil but almost always killed a pilot's business. Dosage accuracy, correct mixture ratios, and environmental knowledge were key factors in an Ag pilot's economic success.[24]

As Porter put it years later, "we got tied in with a good airplane poisoning company and a good chemical company, so we have been their customers for around 20 years. As farmers, we tried to help the airplane company by furnishing an all-weather landing strip clear of houses and trees….The farmer can help by having the poison at the landing strip on time and by agreeing on the kind of poison to be used the next day."[25] Landowners, then, also had responsibilities. They needed to be on time with correct mixtures and crop specifications and be able to at least describe the infestation problems in some detail.

Pilots and landowners further north in the Plains held a similar aerial spraying ideology. Only in the most extreme circumstances would farmers hire a crop duster. Farmers in Plains states like Kansas during the 1930s and 1940s were influenced by the chemurgy movement and had a familiarity with more traditional methods of pest control such as observation, manual weed removal, and selective poisoning. Ground-based chemical application, in their minds, was much safer because aerial spraying was simply too risky.

Figure 8. Curtiss Jenny, ca. 1920s in Kansas. Courtesy of the Kansas Historical Society.

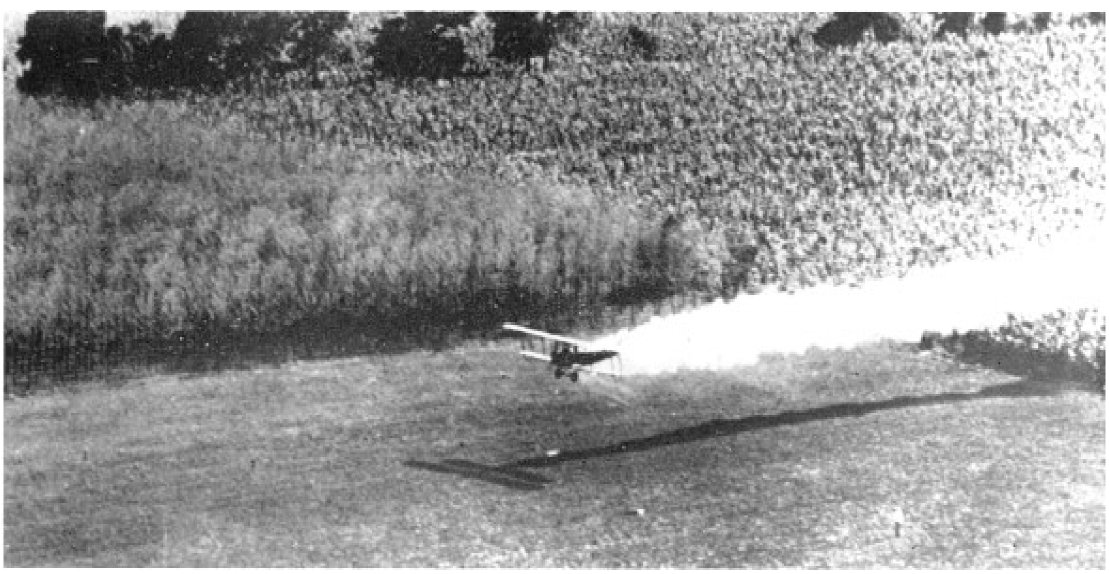


Figure 9. Dusting Catalpa Grove for Sphinx Caterpillar Infestation in Ohio. Courtesy of the USDA.

At the very least, contracting out to an Ag pilot meant turning fields over to an untested "professional." Only when risks to their crops' health were greater than their fears of chemical poisoning or pilot error did farmers consider an Ag pilot.[26] Even in the early years after World War II, many landowners remained ambivalent toward aerial application. New, highly potent farm chemicals encouraged a rapid growth of aerial application, promising new economic possibilities for Plains farmers and a panacea for pests. Nevertheless, landowners worried aloud about the deadly chemicals and inexperienced pilots that flew their spray missions over crops and communities.

From Last Resort to First Response

Regional conditions and agricultural interactions lay behind the transformation of farm planes into chemical applicators. As the *New York Times* reported in 1946, "the age of aeronautical agriculture" continued to expand throughout the region in the 1940s, with groups like the National Flying Farmers promoting the interests of rural farmers and communities. "When it comes to flying," according to the editorial, "farmers are beating city slickers all hollow. Today the greatest concentration of privately owned aircraft is in such wide-open spaces as the rural areas of Nebraska, Kansas, Oklahoma, Texas, Arizona, and New Mexico."[27] Landowners could patrol their fields for human and noxious intruders, allowing the "ranch or dirt farmer to cover a lot of ground fast. Operators of scattered properties can visit them all in one day; repairs to farm machinery can be made quickly, reducing the length of costly shutdowns; windmills and fences can be checked even though they are miles from the homestead, and snowbound stock can be fed by air until the roads are opened."[28] The benefits of farming with an aircraft, claimed the *Times*, specifically related to chemical application. A simple spraying device placed on "the fuselage for seeding—the method has been used for sowing rice, oats, and buffalo grass" could also be used for dusting cotton or "spraying orchards with DDT."[29]

As many farmers watched airplanes become tools in agricultural production, their attitudes about aerial chemical application slowly moved from reluctance to endorsement. Certainly landowners remained cautious about whom they hired to spray their fields, but new possibilities to keep their lands healthy and productive changed perspectives about agricultural aviation from a technology of last resort to one of first response. Ag pilots, however, still had to earn farmers' trust. A reliable applicator was one who combined the local knowledge of a fellow landowner with the chemical-aviation expertise of the agricultural professional. Farmers could not afford mistakes in chemical dosages or mixtures. Their fields, many enduring insect or weed infestations or under threat of pending attacks, needed pilots who would spray accurately and effectively. Pilots also had to be cautious about their contracts. Landowners could easily shift blame (and they often did whether true or not) to the applicator if a job was ineffective by claiming they witnessed cavalier flying or that a pilot failed to read chemical labels.

By 1948, hundreds of aerial application companies existed throughout the Great Plains and the South. Many veterans returning from the war put their aviation experience to use by purchasing war trainers, adding a few basic spraying parts, and offering their "expert" spraying services to local farmers or state officials in their communities.[30] Similar to the transformation of the Curtiss JN-6 after World War I, wartime surplus aircraft in the post–World War II period were cheap and easily adaptable. Pilots could quickly transform trainer aircraft into spraying machines, modifying them for crops and pests of a specific region. However, as both aerial operators and landowners discovered, locally built spray planes also meant operator-specific application practices.

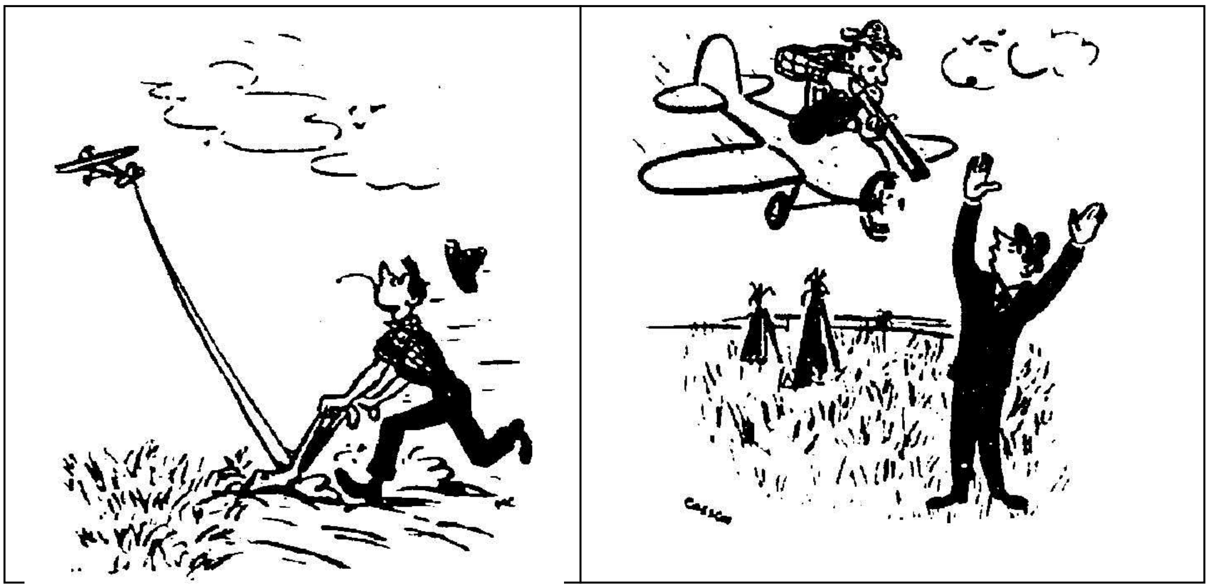


Figure 10. “The Farmer Takes A Plane.” *New York Times*, October 6, 1946.

In the absence of technological standards or application regulations, individual pilots decided on almost all aspects of the aircraft—from chemicals to performance—which often placed fields and communities at the mercy of make-shift aircraft and unreliable pilots. Growing calls, as early as 1946, for design uniformity, application standardization, and professionalism were first heard by Kansas innovators.[31]

The two main agricultural aircraft were the biplane and monoplane. Kansan native Lloyd Stearman (1898–1975) produced one of the most popular models of the first type. He began his aircraft business in the 1920s, converting old biplane trainers from the First World War into multi-purpose commercial aircraft.[32] His popular C-3B model was used throughout the country for mail transport and passenger services and achieved the endorsement of some of the period's celebrity pilots.[33] In 1931, Stearman's business expanded into agricultural aircraft. He altered his C-3B into a spraying machine by installing a basic boom and a series of nozzles. Similar in look and effectiveness to the aircraft used in the Ohio tests, Stearman's aircraft was first to address some of these early operational and conditional problems.

Stearman recognized, as many Ag pilots did, that effective spraying entailed operational simplicity, maneuverability, and chemical accuracy. An agricultural aircraft had to be easy enough for a novice to fly and reliable enough to perform relatively advanced jobs. Stearman's goal, then, was to produce reliable airplanes that pilots could adapt for the job and the place.[34] And his aircraft's popularity testified to this accomplishment. Installing a boom and nozzle system was relatively easy to do on a Stearman; applicators could quickly rework nozzle configurations to get the correct dispersal rates for each crop and pest. One of the main problems with some of the "home-built" trainer airplanes, as Stearman understood it, related to this issue of nozzle spacing and boom type. Variations in droplet size and chemical type could dramatically change the aircraft's swath pattern, which could be the difference between protecting a farmer's crops and killing them.

Nozzle position also related to the safety of the pilot. If placed too close together, the cockpit could be unintentionally sprayed, allowing corrosive chemicals to destroy sections of the fuselage or poison the pilot. Because operators already struggled with chemical inhalation, misaligned nozzles could only increase their risk. Also, fields and crops suffered if nozzle spacing was off. Large drops that clumped together increased the dosage amount per plant, which could burn the crop or poison the soil. Miscalculated dispersals also placed surrounding fields and communities at increased risk of chemical drift and contamination. The success of this basic trainer aircraft in aerial application operations continued to elevate the biplane throughout the 1950s and 1960s as a reliable spray machine.[35]

The second agricultural aircraft model of the postwar period came from the Piper Aircraft Corporation. In business since the 1920s, Piper created a monoplane to compete with the biplane trainer models by designing a plane that was easy to fly and use. During World War II, Allied forces used Piper aircraft such as the J-3 Cub for troop observation, transport, and reconnaissance. In the postwar period, Piper would look to agriculture as a prime market. Despite the company's financial woes hindering overall production, the J-3 Cub and other models grew in popularity among aerial applicators and farmers. Similar to the transformation of the Stearman to an aerial sprayer, pilots improved on the Cub models by adding a simple boom and nozzle system and converting half of the cockpit into a containment hopper. Its mechanical simplicity also related to its popularity. Ag pilots could quickly repair engine problems or fuselage damage and Cub parts were relatively easy to find.[36]

Both models influenced the early postwar trajectory of agricultural aviation. Over the next three decades, a majority of pilots continued to purchase biplane models that largely following the early designs of Stearman and the Piper Cub. Future companies like Gruman Aviation developed new generations of biplane models such as the "AgCat" with this popularity in mind. Piper Aircraft also produced its own agricultural aircraft model in the 1950s—the Pawnee.[37] Pilots, engineers, and aircraft companies across the county also explored how to convert larger, multi-engine aircraft like the Douglas DC-3 or rotary-winged aircraft to compete, but ultimately biplane and monoplane designs won out.

New Technologies and Techniques

Effective aerial application depended upon a plane's chemical and aeronautical performance working within the environmental conditions and regional characteristics. As revealed in Lloyd Stearman's early postwar designs or the adaptation of the J-3 Cub to the "Cut-back Cub," the spray plane's evolution from a hodgepodge of parts to a reliable aerial spraying machine began with its dispersal system, which could adjust to plants, pests, and places. Pilots in the early postwar era struggled with the accuracy of their aircraft due to the varieties of booms, nozzles, and tanks available to them. As farmers used new batches of toxic chemicals on their fields, pilots looked to a new set of tools to protect themselves and the lands they sprayed.

The aircraft's containment tank presented the first challenge. In the beginning, pilots designed their own chemical reservoirs by constructing a metal tank large enough to hold the dust and liquid chemical loads and thick enough to resist the corrosive properties of most agricultural chemicals. Corrosion was especially worrisome because a leaking tank allowed toxic materials to seep into the cabin or through the fuselage into the air. Pilots not only lost expensive product, they potentially could harm soil, plants, or themselves.

Many operators tried to solve this problem by installing a crude set of cloth or rubber linings inside the tank to reduce seepage. This method worked to a point, but chemicals continued to leak into the pilot's cabin or the ground. In later years, as the agricultural aircraft standardized, “safe tanks” became a marketing ploy of aviation companies specializing in aerial application and ultimately a legal requirement by the federal government.[38]

Additionally, pilots installed agitators, air vents, and a series of pumps that consistently mixed the tank’s contents while airborne. They devised a variety of circulation systems that typically had a filter, mixer, and air vent inside the tank as well as a miniature external propeller or hydraulic pump system that used airspeed or electricity to maintain agitation and dilution during flight. Many pilots also installed measuring windows or sight gauges that showed chemical levels. This allowed operators to quickly discover if their tanks were leaking or if a miss-spray occurred.[39]

The second challenge was environmental. Once pilots loaded up, taxied out, and took off, the chemical mixture and containment were only two of the many factors involved in avoiding plant injury or soil contamination. The main trick for pilots was to release exact amounts of chemicals for specific pests and crops while making as few passes as possible. Spraying along rows of corn in Iowa and Nebraska or fields of wheat in Kansas required pilots to maneuver back and forth across the cropland in parallel lines, holding the distance between flight lines and swath width to effectively match spray patterns evenly over the field. And successful swath spacing depended on a variety of human and nonhuman factors.[40]

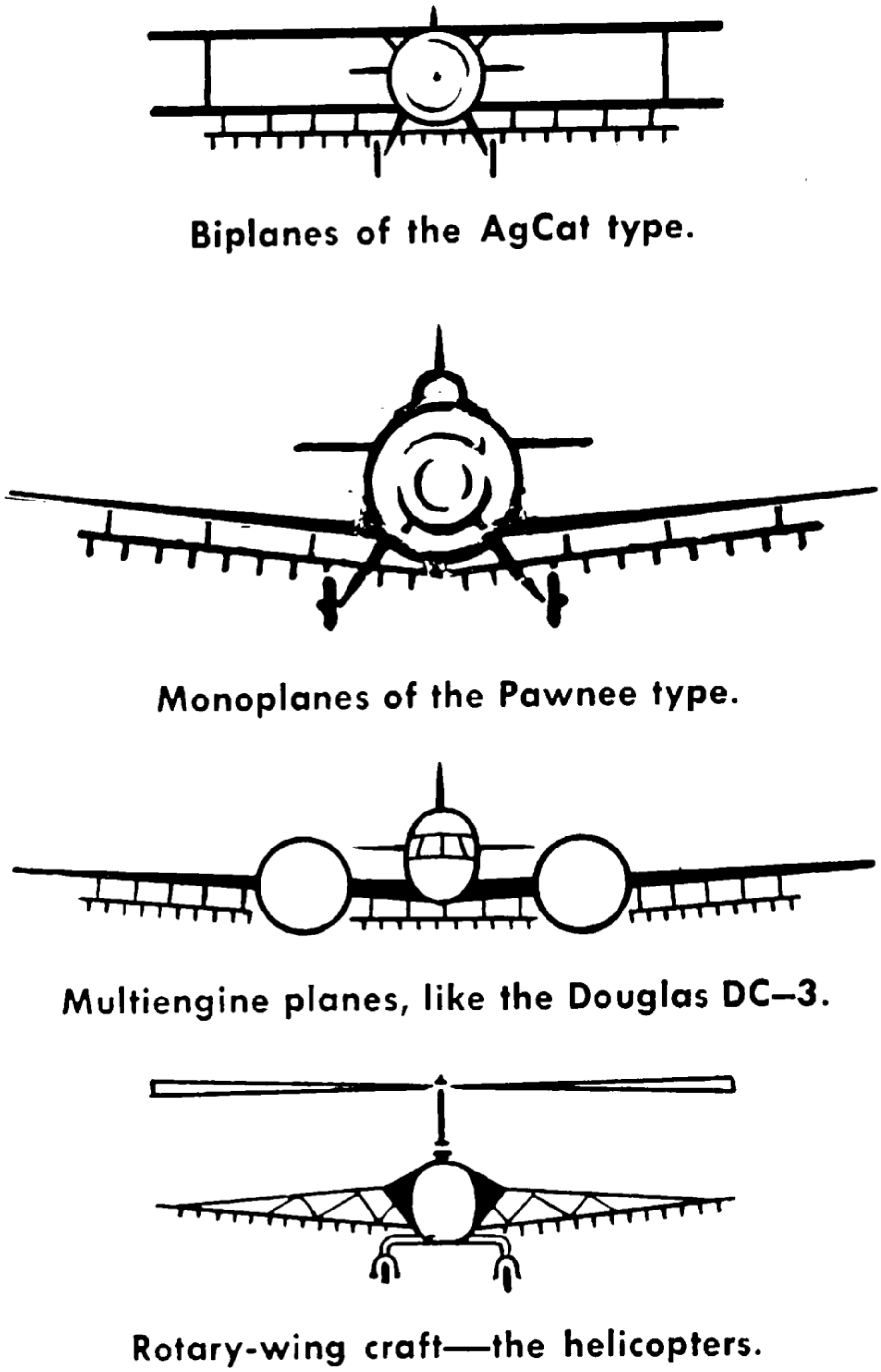


Figure 11. Basic profiles the postwar aerial sprayers. Reprinted from "How To Spray the Aircraft Way: A Guide for Farmers and Spray-Plane Pilots," *Farmer's Bulletin No. 2062,* (Washington, D.C.: GPO: June 1954), 10.

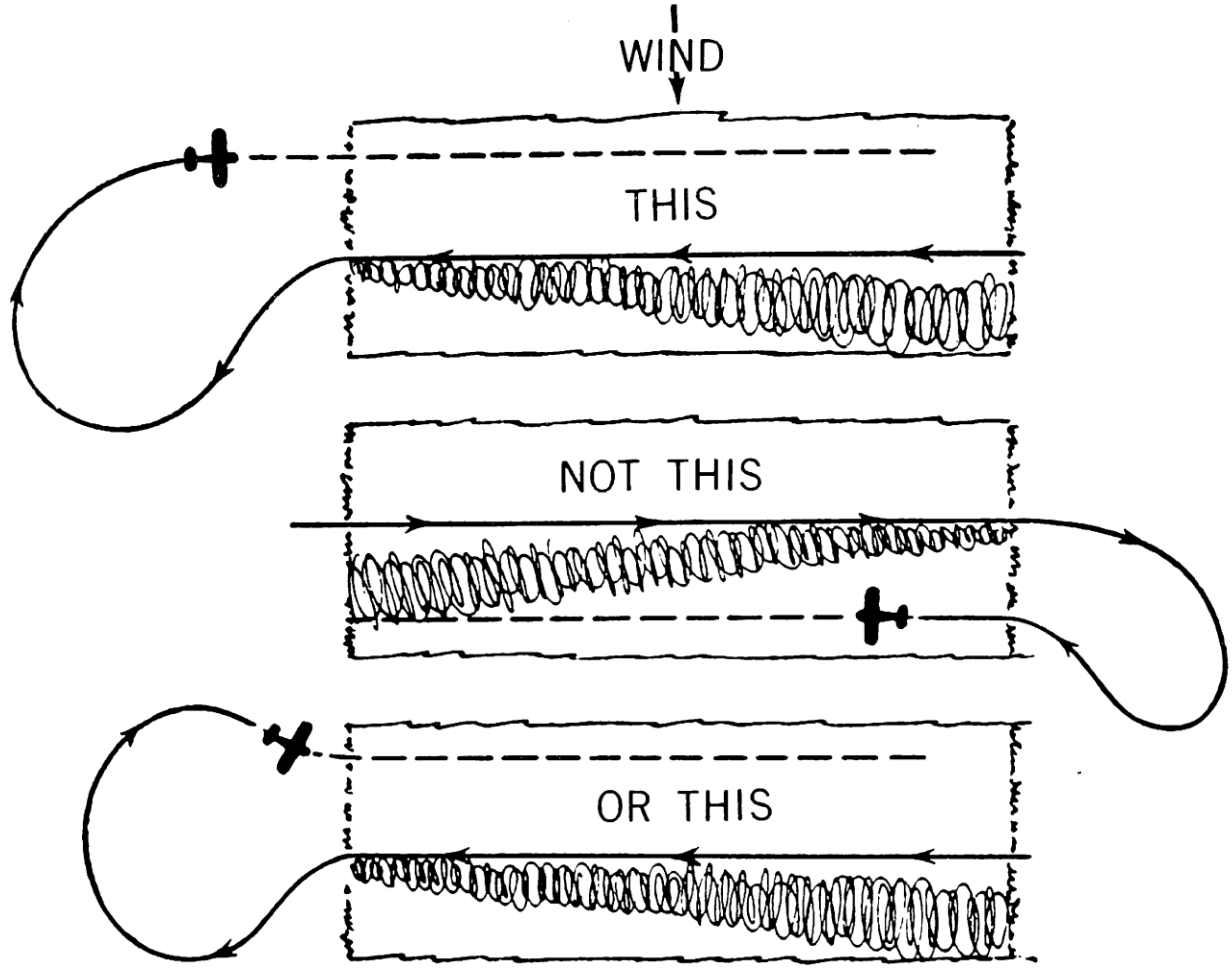
Operators had to understand the climatic and meteorological patterns of the spray location. As air and land temperatures warmed throughout the day, accuracy and chemical effectiveness diminished, creating an air-to-ground temperature differential that if unchecked, could create dangerous and unpredictable swath patterns. In the early morning or late-evening, ground air temperatures and temperatures twenty or thirty feet above the surface were similar enough to allow successful chemical dispersal. As morning changed to midday, temperatures increased, causing a convection process to take place. This produced thermal currents that lifted chemical dusts or liquid particles into the air, carrying them well beyond the intended pattern.[41]

Weather conditions also affected swath dispersal. Wind, more than any other factor, provided for a successful treatment or deadly mistakes. Pilots usually began spraying early in the morning when fields are still and ground-to-air temperatures are uniform to mitigate this danger, but even the slightest changes in the atmosphere or wind pattern could ground the operation. Certainly any major aerial disturbances such as a thunderstorm immediately halted spraying, even against the behest of farmers who were in the midst of an insect or weed infestation. Pilots had to quickly anticipate if chemical sprays or dusts drifted beyond their targets and if the poisons were evenly distributed over crops or if they settled on only a few sections.[42]

Aerial applicators also needed to know the location of the fields, type of crops and pests, and the geographical landscape of the job. Sprays for wheat pests often differed from those of corn or cotton and also changed based on host identity—weeds required different chemicals and dosages than insects. Landowners occasionally provided pilots with some of this information in the early hiring process but aerial sprayers had to understand the crop type, field locations, and geography of the spray area to ensure that they correctly treated crops with the right dosage while preventing toxic sprays from venturing into other areas. It was not enough for pilots to simply fly the aircraft. They needed training in crop recognition, chemical toxicity, and the biological properties of weeds, insects, and soil.[43]

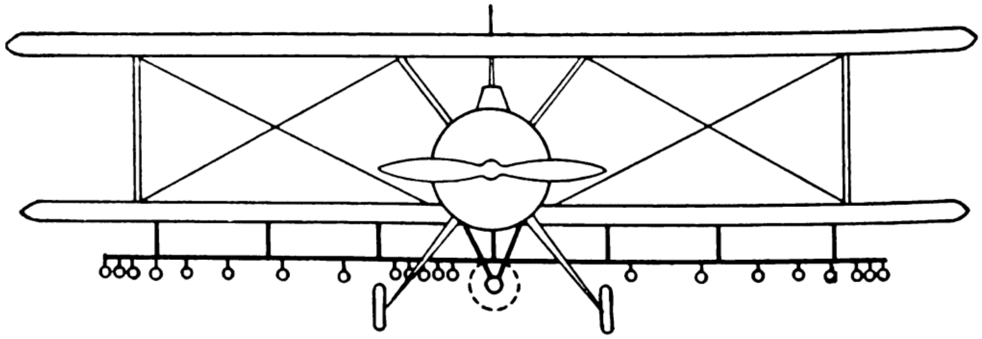
A third challenge involved computation. Pilots were required to calculate the correct deposit pattern and swath spacing for each job. Since chemical mixtures and their dispersal rates related to the health and safety of the pilot, farmer, community, and the environment, aerial operators practiced with water-testing. To achieve an accurate swath or the dispersal strips or sections of a surface in the plane's wake, aerial applicators adjusted their nozzle spacing and boom width based on the label information of each chemical (or the stated mixture ratios of multiple chemicals), and the environmental conditions of the location.[44]

Pilots wanted swath patterns that stayed within the designated field and effectively treated plants. Their goal of uniform coverage meant spray patterns that were almost perfectly spaced. Operators had to calculate the exact distance between the first pass and the second or third coverage attempts in order to guarantee that each corn or wheat stalk was evenly covered. A slight miscalculation or variation in each dispersal attempt could result in a pattern that clumped in the middle. In this scenario farmers lost on both fronts. Some sections of their fields would burn from excessive chemical exposure while other sections went without any treatment, which allowed infestations to continue unabated.[45]

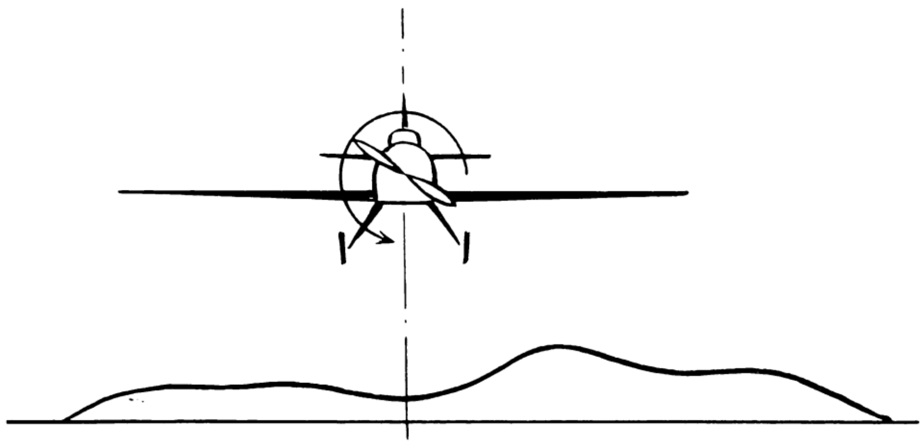


Flight path during turnaround.

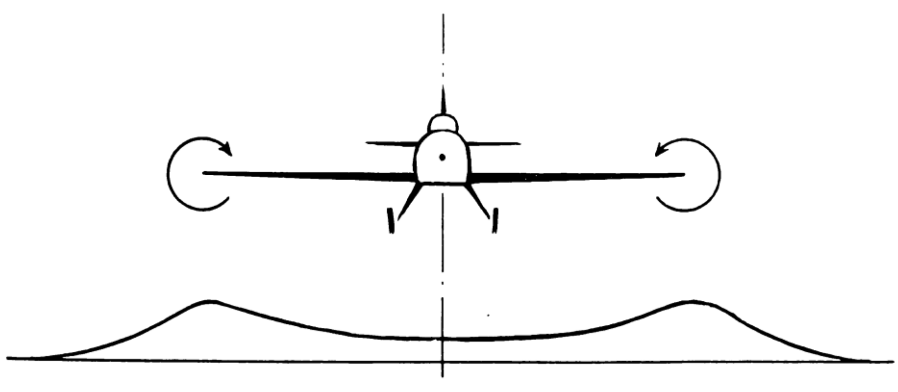
Figure 12. Reprinted from “How To Spray the Aircraft Way: A Guide for Farmers and Spray-Plane Pilots,” *Farmer’s Bulletin No. 2062* (Washington, D.C.: GPO: June 1954), 13.



Nozzle spacing.



Deposit tendency: Pattern distorted by propeller airstream.



Deposit tendency: Excessive spray in wingtip vortices.

Figure 13. Reprinted from "How To Spray the Aircraft Way: A Guide for Farmers and Spray-Plane Pilots," *Farmer's Bulletin No. 2062* (Washington, D.C.: GPO: June 1954), 20–21.

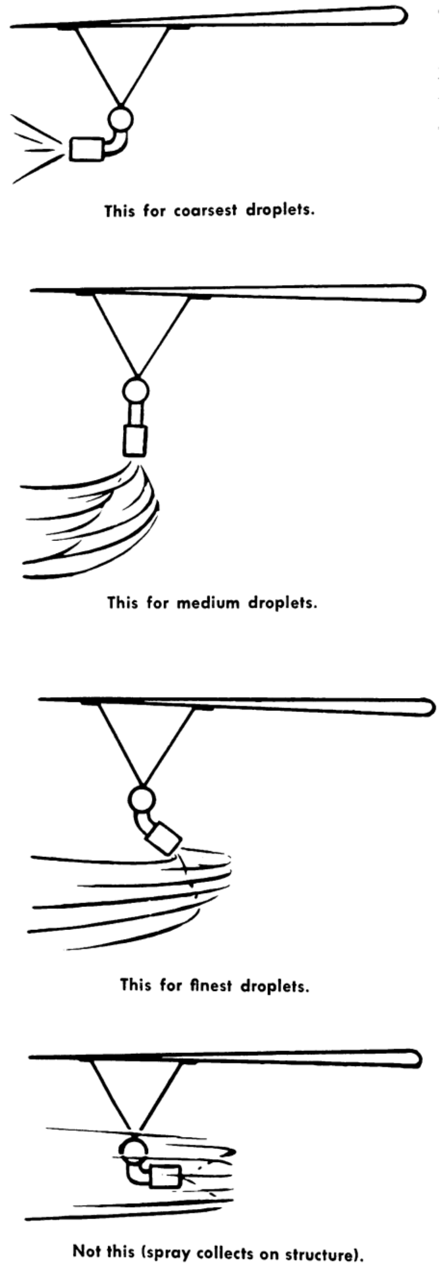


Figure 14. The Ag Plane Nozzle System, 1954. Reprinted from “How To Spray the Aircraft Way: A Guide for Farmers and Spray-Plane Pilots,” *Farmer’s Bulletin No. 2062* (Washington D.C.: GPO: June 1954), 22.

Chemical application rates also mattered. Aerial applicators constantly worried about the dangers of phytotoxicity, or the process by which the chemical's compounds injure plants was a constant concern for aerial operators. Wrong mixtures, like swath miscalculations, harmed fields by either burning the crops due to its overt potency or became too diluted to stop infestations. To achieve accuracy in their mixture-ratios and rate of application for a variety of chemicals, most operators developed two application rate standards. Most jobs required approximately five to ten gallons per acre. By calculating the rate of travel, gallons per minute, and the distance between nozzles, pilots could determine a more exact application rate that would also help them accurately measure dilution rates of each chemical (see Table 1).

All of these factors shaped the development of the postwar spray plane. As Stearman's designs revealed, pilots had to adapt their spraying machines to the regional environmental conditions. Their business' success depended on, at the very least, an awareness of the crop, pest, and chemical interactions of each field sprayed. Applicators needed the ability to change boom and nozzle configurations on the fly. As agricultural aviation moved from southern cotton fields to the grasslands of the Great Plains, farmers and pilots incorporated these human and nonhuman relationships in their approach to the powerful sprays and faster planes that advanced across the skies of Oklahoma, Kansas, Nebraska, and Iowa. Pilots, weed scientists, and landowners in these states argued early on that knowledge, cooperation, and professionalism was the best path to protecting their crops from weeds and insects while also protecting their lands and communities from contamination.[46]

Type	Horsepower	Max Payload For Dust	Max Payload for Spray	Avg. Speed (m.p.h.)	Usual Height Above Plants (feet)	Approx. Effective Swath for Dust (feet)	Approx. Effective Swath for Spray (feet)
Piper Cub (monoplanes)	65-90	250-300	30-40	50-70	4-10	40	40-100
Stearman (biplanes)	220-450	600-1200	60-160	85-100	4-15	50-70	40-120

Table 1. An Example of Dispersal Rates and Payload Requirements. Reprinted from *The Handbook of Agricultural Pest Control* (New York: Industry Publications, Inc., 1951), 112.

Early Warnings and Local Precautions

From 1945 to 1955, the Great Plains became the next hub of aerial application development. While cotton production remained tied to the agricultural aviation industry and continued to influence its trajectory for decades to come, the production of corn, wheat, and other crops helped place the Great Plains at the forefront of aerial application development. The divide that began as early as the 1920s between those who embraced any form of chemical application and those who argued for selectivity and accuracy continued to widen. Farmers throughout the South increasingly endorsed pilots and application techniques that stressed volume over risk. Many operators complimented by expressing, as historian Pete Daniel put it in *Toxic Drift*, “a macho and irreverent image to the world.” Some of these pilots “realized that their lives depended upon care in handling pesticides and that their business thrived on accuracy of application,” while others, like those that flew for the Agricultural Research Service control projects, "ignored property lines and displayed little of the finesse shown by private dusters."[47]

Indeed, there were some operators and planters who complained about miss-sprays but most were focused on the racial tensions and crop complications, not the toxic consequences of agricultural chemicals. In the South, health problems among landowners, rural communities, or the land itself simply did not garner the kind of local or state attention that would be noticed in the Great Plains. As Daniel emphasized in *Toxic Drift*, the "vast ecological changes that swept through the rural South were hardly noticed due to the increasing tensions generated by the civil rights movement. The confrontations between black and white farmers largely eclipsed the problems of pesticide poisonings."[48]

Throughout the Great Plains, however, many pilots and farmers continued to critique indiscriminate application and pilot error. They emphasized accuracy in chemical dosage and dispersal and argued that an ecological knowledge of the land should accompany a chemical understanding of mixture rates, spraying-ratios, and toxicity measurements. Spray pilots and farmers, many insisted, could not afford the kinds of mass sprayings that occurred in other regions of the country. The combinations of pasturelands, rangelands, and croplands required aerial operators and landowners to work together to maintain an intimate knowledge of place and land. The variety of crops, geography, environmental conditions, and communities in the Great Plains also required a custom applicator's complete attention because different areas meant different spraying methods and chemical mixtures. While southern aerial spraying habits continued along a path of indiscriminate spraying, practices in the grasslands tended to be more restrictive, emphasizing standardization, spray-pattern uniformity, and a general knowledge of agricultural chemicals.[49]

Midwestern pilots claimed that successful aerial application came from a comprehensive knowledge of chemical and agricultural expertise. They embraced relationships with experiment station personnel, university scientists, and state policymakers. Many sought to learn the science behind chemical application and the aerial/chemical risks involved in the process. Pilots also wondered about plant and insect resistance. This desire for professionalism and risk management inspired applicators throughout the region to organize local clinics and conferences. Their meetings emphasized studying the ranges of toxicity on various crops and pests, researching aerial techniques, and discussing how to work with landowners and lawmakers.[50]

Spraying the Kansas Way

One of the first steps in applicator professionalism began in Hays, Kansas with Donald E. Pratt and P-T Air Service. Pratt started building his crop spraying operation in 1946 by emphasizing both his aeronautical and chemical expertise. He learned as much as he could about the newest agricultural chemicals on the market, DDT and 2,4-D at the time, met with state entomologists and weed supervisors to increase his understanding about crop–pest interactions, and then purchased ten, 2,000-gallon tanker trucks, hired a ground crew, and went to work. In two years, Pratt had spraying contracts with a majority of western Kansas wheat farmers and a reputation for accuracy. His mobile, 20,000 gallon strong arsenal included a combination of ground and aerial sprayers that could treat over 7,000 acres in one morning.[51]

Considered the “Spray King of the West” by many of his contemporaries, Pratt established a western Kansas aerial spray tradition that combined equipment accuracy and spraying education with a savvy business plan.[52] In relatively short time, as Ag pilot Dick Reade of Missouri recalled in Marby Anderson’s *Low and Slow: An Insider’s History of Agricultural Aviation*, Pratt “had contracted for virtually all of the wheat land in western Kansas…mostly applying 2,4-D. He had everything in that country tied up and it was really quite amazing how well we managed to get the jobs done.”[53]

Pratt’s reputation encouraged many would-be pilots throughout the region like Reade to spend a summer or two working for P-T Air before they returned home to start aerial spray businesses of their own. However, it was not enough for these applicators to simply show up for a job. To work for Pratt, pilots had to attend his spray clinic, an intense summer “working” course. First, every pilot under his employment had to attend a two-week spraying school at P-T Air where they learned how to calculate chemical dosages, various spraying techniques such as swath management, and the scientific intricacies of pest management. After they passed Pratt’s exams, the newly minted aerial applicators were incorporated into his crew, which, according to *Aviation Week*, typically included “four flagmen, two planes and four pilots (or four planes and eight pilots), two tank trailers and drivers, and a station wagon with supervisor.”[54] While pilots were spraying one field, clinic supervisors would direct extra flagmen from field to field, preparing for the next aerial application. Pratt essentially taught as he worked, dispatching both pilots and ground crews, with basic county maps, to each new field only minutes before it was sprayed. Pilots worked in shifts of forty minutes to an hour, depending on the crop, infestation danger, and instructional activity.

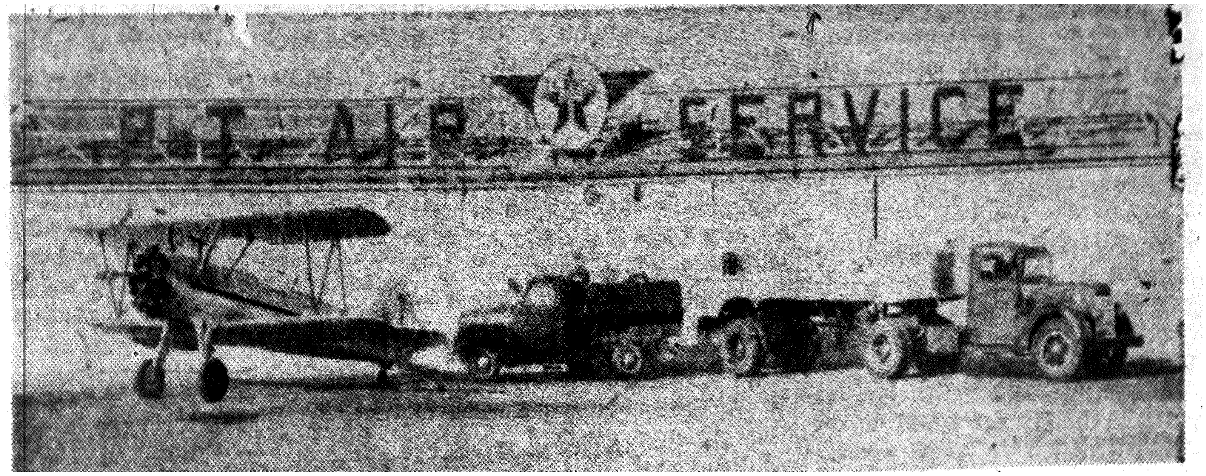


Figure 15. Don Pratt's P-T Air Service in Hays, Kansas. From the *Topeka Daily Capital*, Sunday, 20 February 1949.

The P-T Air spray clinic was popular among the region's pilots because they received the aerial experience and a working knowledge of regional conditions—not to mention a share of the profits. Pratt often made arrangements so pilots could "fly for him during the spraying season and work for chemical companies or local concerns at other times. This way it is possible to always have highly experienced pilots to do this specialized type of work."[55] When farmers in other states hired an aerial applicator that had worked with Pratt, they could be reasonably sure of the pilot's attention to accuracy, mixtures, and field boundaries. Pratt also made money on his education venture by having the ability to treat thousands of acres of western Kansas wheat and rangeland at the same time.

P-T Air's fame did not stop with local farmers or pilots; state and federal officials sought his expertise as well. Pratt continued to build working relationships with university extension officials and regional chemical representatives in the hopes of achieving a scientific knowledge of the latest toxics. Even the Civil Aeronautics

Administration (a precursor to the Federal Aviation Administration) took notice. They used P-T Air as a primary case study to inform aerial spraying operations and regulation at the federal level.

Pratt's focus on accuracy, toxicity, and risk was one part of a larger discussion going on in the postwar period among Kansas farmers, pilots, and officials. The postwar influx of highly potent chemicals and application technologies had produced as many questions as answers. Farmers worried that the rapid expansion of chemicals and aerial applicators were developing too fast with unchecked dangers to their fields and communities. Pilots were concerned that the stereotypes of a "dirty and idiotic sprayer that was addicted to risk" would hinder their business or encourage unnecessary regulations. Officials sought a balance between agricultural production and regulation of chemicals and their application technologies.[56]

In an attempt to assuage these anxieties, Kansas State Agricultural College in conjunction with the Kansas Board of Agriculture, hosted a series of conferences beginning in February 1949 hoping to develop a state plan of risk management and chemical use practices. The first meeting held on the Kansas State campus focused on the varieties of misunderstandings between pilots, landowners, and officials about chemical potency and equipment accuracy. In the *Kansas Farmer*, reporter Dick Mann noted that a majority of farmers and pilots from several Midwestern states arrived at the conference wanting to simply blame each other for application mistakes. Operators openly criticized farmers at some of the panels for using newer, more potent chemicals without regard to pest or even field acreage. One pilot complained to Mann that a farmer asked him to spray 80 of his 92 acre field. The pilot, assuming the field was only 80 acres, "made his mix for that acreage and went to work. He later found there were 92 acres in the field. This meant his application was not correct if he covered all 92 acres, or else he had to land and make another batch to finish the 12 acres overlooked by the farmer." Pilots also challenged farmers at the conference on their knowledge of various pest lifecycles, especially when it came to weeds. As another operator explained to Mann, farmers often misjudged the growth rates of weed: "time after time farmers insisted that I spray their fields even when I told them it wouldn't do any good. Then they were dissatisfied when their weeds didn't fall down."[57]

Farmers responded with their own set of critiques about aerial applicators. First, landowners complained that operators had trouble keeping sprays within field boundaries. Drifting chemicals, they argued, not only destroyed crops but hurt their neighbors and innocent bystanders. State weed director Ted Yost confirmed this sentiment in his support for a statewide control bill that tried to address the concerns of both landowners and applicators: "a control bill is necessary to protect the farmer hiring the service, and to protect his neighbors and other innocent bystanders." According to Yost, often times "the farmer has paid his money and the operator is out of the state before results on the job are apparent. Last year we had definite complaints for damage to crops near fields being sprayed. We think [a] control bill will protect the legitimate operators."[58]

Farmers feared the rapid growth of aerial spraying, insisting that pilots could get away with sloppy or even fraudulent work. As Mann reported, since "everybody and his Dutch uncle wants to get into the spraying business," many landowners were "deeply concerned over the possibilities of this thing [aerial application] getting out of hand."

Landowners sided with state agricultural officials for increasing the size and scope of oversight. Pilots, they insisted, should take their examinations through the Board of Agriculture, allowing the state officials to evaluate aeronautical ability, spray technique, and proper mixture and dispersal methods.[59]

Pilots, however, remained skeptical of regulation proposals like a state chemical control bill. As Mann suggested, they understood "that they have a big responsibility and say they are willing to accept it. Most of them feel there should be registration of operators. Many of them think they also should post bonds, although [sic] they point out that under present laws they can be sued anyway for fraud of damage. They have their own reputations at stake and do not want to lose a paying business by doing sloppy work or laying themselves open to damage suits."[60] Roy Mahon, an aerial operator from Dodge City, Kansas and president of the Kansas Flight Operators Association, went even further. The emphasis on regulation and restrictions would help protect the lives and lands of the farmer from miss-sprays, Mahon argued, but many "spraying jobs are emergencies that require large numbers of units during a short time. There will be times when we desperately need to call in all the planes we can get to meet such an emergency. Restrictive laws might cost the farmers thousands of dollars in the emergency area by keeping out distant operators who otherwise would be available."[61]

By the end of the two-day affair, contention changed to consensus. Landowners and pilots both agreed that their embrace of new agricultural chemicals came from a shared desire for healthy lands, which sharing the risks of chemicals equally. Aerial applicators left the conference viewing their roles in Kansas agriculture akin to physicians of the fields. A move toward professionalism and standardization allowed them to adequately protect crops from the hazards of weeds, insects, and disease. Farmers departed with assurances from Board of Agriculture officials of increased oversight of aerial spraying as well as a clearer understanding of the various factors involved in chemical application.[62]

Figure 16. Roy Mahon Preparing to Treat Western Kansas Wheat, ca. 1949. Courtesy of the Kansas Historical Society.

In November 1949, Kansas spray pilots, farmers, and officials returned to the Kansas State University campus to continue their debate over application practices, risks of chemical use, and latest infestation assessments for Kansas crops. According to the *Journal of Agricultural Chemicals*, most sessions addressed the risks of weeds and insects versus the safety of farmers and their lands. Numerous state and federal officials attended the three-day meeting and presented various application methods of fertilizers and current agricultural chemicals. University faculty, state policymakers, and the public heard researchers address the poisonous compounds of 2,4-D, the various weed threats to Kansas wheat, the toxicology and residue problems of new insecticides in airplane application, and the correct formulas for chemical mixtures and application rates.[63]

Donald Pratt attended, reporting on the aerial spraying innovations in western Kansas. He participated in a 1949 roundtable discussion about his experiments with aerial application of insecticides and presented a paper on the aerial spray equipment problems that he had encountered in his western Kansas operations. His panel also addressed the basic communication errors between ground operators and pilots, effective swath widths when deploying chemicals, and summaries of aerial hazards and accidents for the 1948 season and what might occur in the 1950 season.[64]

The development of postwar aerial application had much to do with the regional interactions of pest, pilot, and farmer and their relationship to the farm-chemical landscape as the influence of war or agriculture production. Infestation threats may have pushed pilots and farmers to develop aerial application technologies and accept more potent chemicals to do the job, but not without a sense of the risks. Local spray operations like P-T Air played an integral role in raising the awareness of farmers and community members toward the dangers of aerial spraying and agricultural chemicals. In the 1950s this emphasis on standardizing risk would encourage even further calls for safe, effective spraying. “Protecting by poison” became the call of aerial applicators and the marketing ploy of agricultural chemical companies expanding the pesticides’ scope and influence.

Notes

[1] USDA, "How To Spray the Aircraft Way: A Guide for Farmers and Spray-Plane Pilots," *Farmer's Bulletin No. 2062*, (Washington, D.C.:G.PO: June 1954), 3.

[2] *Topeka-Capital Journal*, 29 May 1969.

[3]See Edmund Russell, "'Speaking of Annihilation': Mobilizing for War Against Human and Insect Enemies, 1914-1945," *Journal of American History*, 82 (March 1996): 1506.

[4] Please see Deborah Fitzgerald's *Every Farm a Factory: The Industrial Ideal in American Agriculture* Joe Anderson, *Industrializing the Corn Belt: Agriculture, Technology, and Environment, 1945–1972* (DeKalb: Northern Illinois University Press, 2009); Kendra Howard-Smith, "Antibiotics and Agricultural Change: Purifying Milk and Protecting Health in the Postwar Era," *Agricultural History* 84.3 (Summer 2010), 327–351; R. Douglas Hurt, *American Agriculture: A Brief History* (Ames: Iowa State University Press, 1994); James Sherow, "Environmentalism and Agriculture in the American West," in R. Douglas Hurt, *The Rural West: Since World War II* (Lawrence: University of Kansas, 1998), 58–71.

[5] See James C. Giesen "The Herald of Prosperity," Tracing the Boll Weevil Myth in Alabama," *Agricultural History* 85 (Winter 2011): 24–49.

[6] Ibid.

[7] Ibid.

[8] Julius A. Truesdell, "Spraying From Air: New Use for Flying Machines in Government's Effort to Conquer Boll Weevil Scourge," *New York Times*, January 8, 1922.

[9] Ibid.

[10] Ibid; Eldon W. Downs and George F. Lemmer, "Origins of Aerial Crop Dusting," *Agricultural History* 39 (July 1965): 123–135.

[11] USDA Yearbook, "Insects," (Washington, D.C: GPO, 1952), Pink bollworms, plate VI).

[12] "Two New Pink Bollworm Infestations Found in Texas; Department Fights Pest," *USDA Weekly News Letter* (February 19, 1919), 11; "Aeroplanes Used To Discover Outlaw Texas Cotton Fields," *Flying* (April 1919), 255–256.

[13] Ibid, *USDA Weekly News Letter*.

[14] Ibid., Hurt, "A Brief History," 222–227; Also see Willard A. Dickerson et al., eds., *Boll Weevil Eradication in the United States through 1999* (Memphis: Cotton Foundation Publisher, 2001); Mississippi State University Cooperative Extension Service, "Management and Control of Boll Weevils," *Publication 1830* (1992), 2.

[15] Ibid, *Flying*, 255–256.

[16] Ibid.

[17] "Spraying From the Air: New Use for Flying Machines in Government's Effort to Conquer Boll Weevil Scourge," *New York Times*, January 8, 1922.

[18] Ibid., "Origins of Aerial Crop Dusting," 123–135.

[19] Ibid.

[20] Ibid.

[21] Texas A& M Experiment Station, *Handbook on Aerial Application in Agriculture* (College Station, Texas A&M Press, December 1956), 79–80.

[22] Ibid.

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] James Senter Brazelton, "Toxic Plots Make Old Orchard Land Infertile," *Kansas Farmer*, 20 September 1941.

[27] "The Farmer Takes a Plane," *New York Times*, October 6, 1946.

[28] Ibid.

[29] Ibid.

[30] Ibid; "Industrial Use of Aircraft Growing," *Aviation Week*, 28 February 1949; "The Airplane Brings a New Type of Living to the Farm," *Capper's Weekly*, 13 July 1946.

[31] Ibid; Also see Marby I. Anderson, *Low and Slow: An Insider's History of Agricultural Aviation* (Perry, GA: AgAir Update, 1986); Brian Baker, "The Impact of World War II on Agricultural Aviation in the United States," Master's Thesis, Brigham Young University, 1965.

[32] Lloyd Stearman was part of the rapidly expanding aviation collective that formed after World War I in Wichita, Kansas. This group included Walter Beech, Clyde Cessna, and E.M Laird. See Craig Miner's *Wichita: The Magic City: An Illustrated History* (Wichita, KS: Wichita-Sedgwick County Historical Museum Association, 1988), 149–166.

[33] "Lloyd Stearman," Kansas Historical Society, http://www.kshs.org/kansapedia/lloyd-stearman/16724; "Lloyd Stearman, 76, Dies; Pioneer Plane Designer," *New York Times*, 5 April 1975, 32.

[34] Ibid., *Low and Slow*.

[35] USDA, "Aerial Application of Agricultural Chemicals," *Agricultural Handbook No. 287*, (Washington D.C.: G.P.O., May 1965), 1–31.

[36] See *Journal of Agricultural Chemicals*, May 1951; Devon Francis, *Mr. Piper and His Cubs* (Ames: Iowa State University Press, 1973); Historical Video Production, *Crop Dusters: America's Forgotten History* (2004).

[37] See William Schweizer, *The Ageless Ag-Cat: The Forty-Year History of the Ag-Cat Agricultural Airplane* (Bluffton, South Carolina: Rivilo Books, 1995).

[38] Ibid., USDA *Spraying the Aircraft Way*, 1–30; Also see: H.R. Quantick, *Aviation in Crop Protection, Pollution and Insect Control* (London: Collins Professional and Technical Books, 1985).

[39] Ibid., USDA, "Aerial Application of Agricultural Chemicals," 1–30; Brent Connor, interview by author, Spring 2010, in Medford, Oregon. Tape Recording.

[40] Ibid.

[41] Ibid., 25.

[42] Ibid.

[43] Ibid. Also see Dick Mann, "A Bear by the Tail?" *Kansas Farmer*, 5 March 1949.

[44] "Phytotoxicity," in H.R. Quantick's, *Aviation in Crop Protection, Pollution and Insect Control* (London: Collins Professional and Technical Books, 1985), 420.

[45] Ibid., USDA, "How To Spray the Aircraft Way: A Guide for Farmers and Spray-Plane Pilots;" Also see the Texas A& M Experiment Station, *Handbook on Aerial Application in Agriculture* (College Station, Texas A&M Press, December 1956).

[46] By 1950, the North Central Weed Control Conference recommended that custom applicators adapt their technologies and techniques to the chemicals in their planes and the environmental conditions of the Great Plains. See E.H. Sorensen, "Equipment and Methods of Aeroplane Application" in *Proceedings* (Milwaukee, Wisconsin, December 12-14, 1950), 75–77.

[47] Pete Daniel, *Toxic Drift: Pesticides and Health in the Post-World War II South* (Baton Rouge: Louisiana State University Press in association with Smithsonian National Museum of American History, 2005), 55.

[48] Ibid., Daniel, *Toxic Drift*, 22–23; Also see Daniel's chapter on aerial spraying in *Lost Revolutions: The South in the 1950s* (Chapel Hill: University of North Carolina Press and the Smithsonian National Museum of American History, 2000), 61–90.

[49] Ibid., Mann, "Bear by its Tail."

[50]Ibid; Also see "The Iowa Spray Clinic," *Aviation Week*, March 1950**.**

[51] "Spray Combine: Kansas Operator Employs 40 Planes in a Big-Time Crop Dusting Business," *Aviation Week*, June 7, 1948, 34; *Topeka Capital Journal*, February 20, 1949, 2; "Commercial Aviation in Cheyenne County," *The History of Cheyenne County, Kansas* (Cheyenne County Historical Society, Curtis Media Corporation, Dallas, TX: 1987), 146–147.

[52] Ibid., Anderson, *Low and Slow*, 56–57.

[53] Ibid., 57.

[54] "Spray Combine," *Aviation Week*, 34.

[55] *Topeka Capital Journal*, 20 February 1949, 2; "Commercial Aviation in Cheyenne County," *The History of Cheyenne County, Kansas* (Cheyenne County Historical Society, Curtis Media Corporation, Dallas, TX: 1987), 146–147.

[56] *Topeka Capital*, 20 February 1949; *Capper's Weekly*, 13 October 1945.

[57] Ibid, Mann, "A Bear by the Tail."

[58] Ibid.

59 Ibid.

60 Ibid.

61 Ibid.

62 Ibid. Mann actually began his report with this consensus sentiment: Kansas farmers may have a bear by its tail, but fortunately they can tame it. That's the impression I got from attending the Aerial Agricultural Spraying Conference at Manhattan, February 24. Incidentally, it was the largest aerial spraying conference ever held in the United States with between 400 and 500 persons present for the 2-day education meeting. Here is the problem, as brought out at the conference. *There are many new herbicides and insecticides on the market now that will control weeds and many of the worst insect pests that destroy crops. These chemicals compare with some of the new miracle drugs in medicine. They have the power for tremendous good, but they also have the power for great harm if improperly used.*

Almost overnight, these powerful chemicals have come into widespread use, in spray or dust form, by both aircraft and ground equipment. Kansas farmers last year sprayed at least a million acres of crops—mostly wheat—for weed control, and may spray 1.5 million acres this year. Demand last year was far ahead of the equipment and trained personnel needed to do the job….*With this information as background you can see that many persons are deeply concerned over the possibilities of this thing getting out of hand* (emphasis mine).

63 "Airport and Aerial Spray Conference, November 30–December 1-2, 1949," 1–2, in the Department of Entomology Records, 1904–1980, L. D. Richard and Marjorie J. Morse Department of Special Collections, Kansas State University.

64 F.L. Timmons, "Airplane Application of Herbicides," *Proceedings of the 11th Annual Western Weed Conference* (Bozeman, Montana: February 2–4, 1949), 36–37.

Chapter 4: Marketing Toxicity and Standardizing Risk

The use of chemicals as weed killers has increased explosively [sic] during the past ten years. This has brought with it a growing need for more exact knowledge, for proper use of these chemicals. Such information is essential to the effective and safe use of these chemicals as well as to maintenance of application equipment, proper knowledge, moreover, may mean the difference between a profitable operation and one that loses money. For the most effective use of herbicides, it is necessary to know not only that crops and weeds may be treated with the material, but also a number of other factors, for example, one should know what may increase or decrease the effectiveness of the treatment, or if the chemical remains active in the soil. Moreover, it is imperative to know what to expect, both in the handling and effectiveness of the formulated product, by such information it is often possible to avoid many difficulties.[1]

From "Agricultural Chemicals" in the *Air Applicator Information Series, Volume 1*.

We cannot foresee all of the possible consequences or side-effects of the use of the new herbicides, but we can at least profit by the past, and at times bitter, experience with 2,4-D. Early in the developmental stage—concurrent with testing of herbicidal efficacy—sufficient chemical, physical, and toxicological data should be obtained in order to know the limitations and precautions which eventually must be observed in applying these weed-killers in the field. If we do not profit by past experience to the degree that we are able to anticipate future developments, then individually and collectively we lack the circumspection that is the mark of true research scientists. Of course all of you know this much better than I do.[2]

From K. S. Quisenberry's "Weed Control in the Agricultural Research Program," in *Proceedings of the North Central Weed Control Conference* (1949).

Another part of pesticides' transformative power in Great Plains agriculture was the ability to reform older farming concepts that stressed simple eradication into views of chemical conservation that addressed the health and welfare of a larger socio-environmental community. The marketing approaches of pesticide companies and aerial spraying outfits reveal that agricultural chemicals altered farming methods but also that producers groped toward a definition of poisons that related to regional changes and dangers. The Du Pont corporation's slogan that Americans could "live better through chemistry" meant something different in the fields and rural airstrips of Kansas, Nebraska, and Oklahoma than in the nation's cities.[3] Chemical progress had its hazards and farmers, weed scientists, and aerial applicators were worried about its economic and health costs. Most did celebrate the potency and promise of pesticides, but at the same time, they expressed concerns over their rapid rise and potential dangers. Many were also troubled at the move from older chemicals such as DDT or 2,4-D to chemicals of high toxicity such as parathion—what the *Aerial Applicator's Information Handbook* described in 1951 as "poisons of terror."[4] In response, a host of advertisements, industrial studies, and personal testimonies announced that the value of farmland could only be maintained through the safe, knowledgeable use of pesticides. Companies and custom applicators needed to recognize that these potent, invisible implements had very visible consequences. The ability to protect also meant the capability to harm.

Unlike at the national level, where it was easy to condense the business of pesticides into what historian David Kinkella calls the "simple distillations of two chemical viewpoints," when it came to aerial application, selling pesticides in places like the Great Plains required addressing the risks as well as the rewards.[5] Although organizations such as the National Association for Agricultural Chemicals (NAAC) insisted on values of effectiveness and scientific testing as arguments against the growing rebuke of agricultural chemicals by Rachel Carson and others in the 1960s, those same commercial interests were pulled into manufacturing a somewhat different message at the regional and local levels—one that emphasized safety and selectivity, warned against natural toxicity, and highlighted local knowledge. Indeed, many chemical companies and aerial spraying outfits attended NCWCC meetings, collaborated with agricultural experiment station personnel, and sent salesmen to meet aerial applicators in the field.

A closer look at the advertisements, marketing strategies, and scientific studies that appeared in agricultural newspapers such as *Kansas Farmer, Capper's Weekly, the Nebraska Farmer, and Wallace's Farmer*, handbooks such as the *Aerial-Applicator Series*, and reports from national companies like Du Pont, Dow Chemical, or Monsanto throughout the 1950s show connections to the chemical-agricultural landscape of the Great Plains. Marketing toxicity and standardizing risk for developers and applicators included the hazards along with the benefits of pesticides.

As a result, marketers, salesmen, and Ag pilots sold their products or services by stressing protection rather than eradication. The "kill capacity" was certainly part of this literature, but marketers even the protection concept also had to address, in some way, the hazards of chemicals, the selectivity of the mixtures, and the variables of the region. Whether selling poisons or application services, chemical and spraying companies were forced to stress messages that addressed the biological, hazardous, and economic effects of pesticides rather than just an explicit eradication message.[6] A wartime mantra in the grasslands did continue to shape the chemical-agricultural landscape, as in other regions of the country, but it also reflected the consequences of pesticides in farming—not just the battle weary imagery of annihilation.[7] In short, misuse was dangerous but so was nonuse.

* * *

When the North Central Weed Control Conference met in Sioux Falls, South Dakota in 1949, a consensus emerged among weed scientists, applicators, and farmers that guarding crops against the noxious qualities of weeds also meant observing the problems associated with unleashing chemicals into fields, pastures, or rangelands. As we have seen, they could not merely think like producers or agriculturalists but they needed a mindset similar to chemicals and pests. L. L. Coulter's address on the evolution of the pesticides from "Test Tube to Airplane Operators" raised the issue of chemical transference from creation, to applicator, to crop pest requiring careful study and uniform procedures. Consultation and field testing were crucial first steps in releasing any pesticides for agricultural production due to their toxic and often unruly attributes.

As discussed in Chapter two, pesticides posed problems as well as promise. Coulter's argument that aerial applicators should "consult with local agricultural authorities or with fieldmen of reliable commercial companies who are known to have carried out research on the problem with which he is concerned" represented a larger fear among farmers, Ag pilots, and weed experts about the "laissez-faire" growth of aerial spraying taking place in the grasslands.[8]

Ag pilot Donald Pratt made a special appearance to discuss the technical problems of spraying herbicides and insecticides that had been plaguing Kansas sprayers. Other pilots such as Norbert Locke of Iowa State Aeronautics Commission, Ed Youngs of Dakota Aviation (Huron, South Dakota), Jack Hammett of Ong Aircraft Corporation (Kansas City, Missouri), and Fred Montague of Dickerhoff Flying Service (Chanute, Kansas) joined Pratt in analyzing how to adapt technique and tool to the changing chemical-agricultural landscape. All of the panelists agreed that much of the early aerial-spray equipment created by area pilots needed upgrades. For most of them, the relationship between the ecology of pesticides—their toxic interactions with pests, crops, and the land—the limitations of spray technologies and knowledge, and the residual presence of chemicals in the land pointed to inconsistencies and hazards that were at least as dangerous as the pests they were trying to control.[9]

The growth and scope of aerial application and the newer, highly toxic chemicals appearing in the 1950s required additional accuracy. The problems of individually designed pumps, spray booms built using junkyard materials, and inconsistent deployment methods all presented risks that both pilots and weed specialists believed could be fixed with standardization. Complaints of frequently clogged nozzles and corrosion allowed costly herbicides and insecticides to leak onto fields or into the cockpits, damaging crops and sickening pilots. These mounting worries about the acute dangers of pesticides as well as the longer-standing problems of drift, mistaken mixture-ratios, and "lack-wit" applicators were echoed throughout the conference.[10]

Many attending the 1949 meeting had voiced protests the previous year in the 1948 general session on the "Spraying Equipment for Herbicides and other Methods of Application." In that meeting, weed scientist W. P. McDonald of Minnesota admitted that the perfect sprayer and for that matter, the most accurate and responsible custom applicator could never be constructed or discovered. He said, "I am going to open these remarks by saying that the perfect sprayer for the application of weed control chemicals will never be built."[11] Weed control chemicals, according to McDonald, were as diverse as the machines used to spray them. "The kind of machine that will be ideal for one farmer lacks several features which are of utmost importance to his neighbor. For instance, one prospective buyer needs a machine principally for use on row crops. The next individual will spray only small grain." Other farmers, McDonald continued, will use their sprayers "for field work, while his friend also wishes to control livestock parasites and it has been recommended to him that he should buy a sprayer capable of developing pressures up to 400 pounds."[12]

Standardization offered McDonald a large economic incentive, but he insisted that spraying uniformity and selectivity also dealt with technological, environmental, and health implications. Part of McDonald's presentation included a survey of farmers, custom applicators (both ground and air), and weed scientists from other Great Plains states in attendance. Through these questionnaires, McDonald hoped to address the growing expenses and problems in chemical agriculture, especially its fastest growing variety—aerial spraying. What he found spoke directly to the risks and vulnerabilities that worried pilots and farmers.

The survey's first question investigated custom application equipment. Crucial to his query was the relationship between manufacturer, farmer, and the land. The survey noted, "it is scarcely more logical to expect a manufacturer to put out a sprayer that will fit the needs of 40-acre as well as 400-acre farmers; spray row crops as well as close drilled crops; develop pressures from 40 to 400 pounds; deliver volumes from [sic] 5 to 50 gallons per acre, and at the same time fit everybody's pocketbook."[13] McDonald summarized that because variability seemed to define the Great Plains's climate, environment, and agricultural production, a one-size-fits-all spraying machine could never be designed, and even if a "manufacturer should decide to offer a machine embodying these and a great many other features it is quite unlikely that they would make many sales as the cost of the unit would be prohibitive."[14] Each chemical company, therefore, had to decide what kind of sprayer system to endorse and how it would match up with the pests, fields, and production goals of a particular region. At that point, it became “the problem of the sprayer manufacturer to decide what features he must provide in his equipment in order that he may aim at the broadest possible market, with no thought to offering a sprayer that will meet all of the requirements of all the buyers.”[15]

This adaptation dilemma brought on by pesticides, the environment, and crops inherently pitted ground and aerial sprayers against each other. How would growers decide between the two types? McDonald suggested that current risks, economic costs, environmental threats, or health hazards would determine the answers. Weed spraying in the Central Plains, as McDonald saw it, had achieved a unique status due to the extensive winter wheat crops of the postwar era. A decade of growing this “hard” species of wheat throughout the grasslands allowed farmers, weed specialists, and applicators to test how chemicals protect or harm a sturdy crop that was bred to survive the harsh conditions of a Minnesota winter and early spring. “During the past ten years,” explained McDonald, “in the hard spring wheat area we have had a great deal of experience with weed control sprayers of various kinds.” However, he warned farmers in his state and the changes wrought by chemicals and their application technologies did not necessarily extend to other states represented in the NCWCC, so a much larger, more comprehensive study was needed to address the unique and variable conditions attributed to the region.”[16]

According to McDonald’s tabulation of approximately 90 percent of the 1948 harvests had been treated by ground sprayers over agricultural aircraft, but this majority was quickly changing. During the regular growing months, McDonald observed, users seemed to prefer ground sprayers over aircraft application, except for emergency infestations. A noticeable exception, however, came with protecting winter wheat. McDonald concluded, “In the winter area where it was indicated that the division between ground sprayers and aircraft was 35 percent to 65 percent, with the latter percentage being made by planes."[17] McDonald's second question asked all NCWCC members what kind of machine did most operators, farmers, and scientists believe was preferred throughout the grasslands. The majority still held for ground sprayers but those respondents who chose aircraft cited the same reason as those who preferred ground rigs: chemical injury and crop risk. For those who believed, in 1948, that ground application was safer, respondents overwhelmingly described the dangers of chemical toxicity and drift for their technological selection:

> Thirteen replies showed the trend to be to ground sprayers, 2 replies showed a trend to aircraft and one suggested an increasing inertest in dusters. In general, the reasons given for the trend favoring ground sprayers was that this method was handy for the average farmer and possibilities of drift injury were minimized. The one individual who suggested greater interest in dusters said it was due to the inability of farmers to obtain water. In the two cases where aircraft application was coming to the front, the reasons were that this method was very fast and relatively safe where large acreages were involved and there are few susceptible crops. It was also mentioned that where treatment was late in the season, aircraft caused no mechanical injury associated with ground rigs.[18]

McDonald then turned to specific equipment problems associated with pesticides and how users adapted to them. The principle difficulties had to do with the correlation between faulty equipment and environmental contamination. Even the most astute farmer or attentive pilot could have deadly miss-sprays due to malfunctioning planes. Nozzle clogging, corrosive residue, and improper spraying swaths due to poor boom construction presented additional problems. McDonald, however, was very careful not to criticize pilots or manufacturers and instead instead, blamed pesticides: "In all fairness, I believe we should state here that this inconvenience was not necessarily due to faulty construction of equipment. It is certainly well known that several 2,4-D preparations gave difficulty last year when used in high concentrations with hard water. Undoubtedly the precipitate which resulted from this combination had as much to do with clogged nozzles as the improper screening in the line or nozzles themselves." Yet, according to McDonald, these were only some of the pending problems that increasingly plagued custom applicators. Weak boom systems, problematic pumps, "inadequate clearance for row crops, and lack of a marker for the area sprayed" all contributed to chemical hazards that were endangering the lives of crops, livestock, and farmers.[19]

By McDonald's count, aerial sprayers and dusters unfairly suffered some of the greatest scorn by landowners and those living in nearby communities, when the hazards had as much to do with pesticides themselves: "We asked how methods could be improved upon for the future. Several suggested that chemicals should be improved to make them more compatible with hard water. This as has been pointed out, should not be a criticism aimed at the equipment itself. Among other suggestion for improvement were better and more accurate methods of calibration, changes in design of sprayers for adaptation to row crops, improvement of nozzles, faster pumps for refilling tanks, more rugged construction and better control of drift."[20]

McDonald's survey is an early example of the evolutionary forces taking place between the economic goals of commercial farm production, chemicals that could easily move beyond the confines and purposes of their designs, and the human-environmental hazards involved with protecting fields with poisons. Aerial sprayers, in particular, had to adapt their machines and techniques to how chemicals reacted within their booms, pumps, and tanks as well as how they interacted with the landscape once they departed over fields, pastures, or rangeland.

Proper calibration of booms and hoppers, McDonald warned, did not mean pilots and flagmen were exempt from the poisonous consequences of pesticides. He recommended a new method of signaling that would remove humans from direct contact of the aerial swath line. "Some mechanical device or chemical needs to be developed to mark the area sprayed satisfactorily. When an almost colorless solution is applied at low volume, the sprayed area is not discolored and, as a matter of fact, is scarcely wetted. Any overlapping that occurs results in double application which may be harmful to the economic crop and in any event is wasteful. If someone will develop a good system for marking, he will be doing a real service to sprayer operators."[21]

These emerging 1948 calls for collaboration would be expanded in the next year. L. M. Stahler argued that the push for standardizing toxicity in its chemical formulations, dispensary tools, and consequences throughout the Great Plains needed to connect to the larger national picture of aerial application. Stahler was a weed scientist out of South Dakota, but he also represented the USDA at the meeting. Working out of the federal organization's experiment station, Stahler understood, more than most at the meeting, the growing tensions between intrastate and interstate spraying. With the aerial spraying industry only about ten years old (dusting in the nation had gone on much longer), the lack of uniformity, standardization in equipment, and technique endangered pilot reputations, the industry's growth, fields, and communities. Stahler firmly believed all of these issues were interconnected and because the grasslands were a region of high variability in all aspects of chemical agriculture, they provided, at least for him, an effective testing region for developing standards that were safe and effective for the rest of the country.

Stahler argued that the agricultural and environmental variability of the Great Plains played an important role in farmers choosing both 2,4-D and aerial application: "A number of very obvious factors have contributed to the large scale usage of 2,4-D for the control of weeds in this area and likewise to the phenomenal development of aerial application of these herbicides."[22] According to his analysis, the natural durability of wheat, corn, oats, and barley as crops afforded a high tolerance to 2,4-D. This trait offered farmers, weed scientists, and aerial operators a great opportunity to use their fields not only for commercial agriculture but also for chemical test plots. Also, "the absence of localization of 2,4-D sensitive crops in this area devoted to the production of cereals, has favored the use of planes in application of 2,4-D as a fast economic and large-scale operation."[23]

Stahler stressed an important caveat about his study of aerial weed spraying. In 1949, the overall application of 2,4-D actually declined, at least as it concerned Stahler's projections. He wrote, "Several factors contributed to this error in our estimates. [The region] had a very unreasonable growing seasons over the entire area…the southern winter wheat area had an extremely dry fall and [the] early winter seasons were followed by a prolonged period of light to moderate rainfall which extended well through the normal herbicide spraying season." This climatic variability also contributed to a "dry fall and winter result[ing] in poor growth and strands of wheat … that favored the development of annual weeds … [making] the farmer so uncertain of a profitable harvest that he either fallowed his fields or was unwilling to invest the cost of weed control in an uncertain crop."[24]

Stahler correctly noted that this uncertainty was a major force in the development of aerial application and chemical agriculture. A combination of environmental, technological, and unseen chemical forces worked together, in this case, to limit the efficacy of farmers' toxic tools. When "precipitation did come in this area it lasted too long and wheat developed beyond the optimum stage for treatment with herbicides before weather conditions would permit of any large scale aerial spray operations," he concluded.[25] Poor weather conditions contributed to poor crops, actually slowing noxious weed communities but increasing uncertainty about the economic value of the harvest. This same uncertainty, Stahler maintained, existed further north in Nebraska, the Dakotas, and even in some of the prairie provinces of Canada: "In the spring grain area, spring drought with uncertainty of crop prosecution was likewise followed by a long period of rainy weather and high winds that markedly limited the productive spray period. A most important consideration here also is the tremendous increase in the use of ground driven sprayers and dusters for application of herbicides."[26] Farmers were selective in how they used and viewed pesticides because the poisons could be temperamental, ineffectual, or worse, too effective, hurting the very crops and lands they were applied to protect.

Indeed, complications and hazards were informing their decision-making. Uncertainty and risk were shaping their methods. Stahler's findings show the growing intersections between the environment, technology, and the commercial aims of agricultural production within the region. Aerial operators, farmers, and weed scientists inherited qualities, techniques, and viewpoints that related directly to chemicals, whether they were forced to hold off on spraying schedules because of the dependence of herbicidal applications on environmental factors or rethink their application mixtures and procedures because of field proximity, weather, or crop sensitivity. Less healthy crops also meant that noxious weeds were not as numerous, which convinced many farmers to forego their normal treatment schedules, allowing the plants (while reduced in population) to continue expanding their weedy communities.

Woody weed infestations in the rangelands of Texas and Oklahoma also presented a problem for ranchers and cotton growers. Many of these areas simply were designated as multi-use, so ranchers needed grasses and soils that would nourish their livestock and other agricultural animals. They often hired aerial sprayers to dispense 2,4-D mixtures that controlled mesquite and other weeds.

Cotton farmers, however, often grew their crops in these same areas. According to Stahler, as pilots were trying to save one part of the field designated for range, they poisoned the areas selected for cotton and other crops. He notes, “We must not forget the limitations of operation that will be imposed by the hazards of cotton.” Stahler reassured that agriculturalists as well as manufacturers were working on the problem, but in the meantime, operators needed to heed the toxic exchanges inherent in spraying lands that included cotton. “I might add that they have devised several methods of application of certain herbicides that control mesquite and some of these other woody species and which take advantage of the late fall, winter and spring season when cotton is not a consideration.”[27] However, he remained skeptical, at least initially, about applicators adapting new mixtures to address the problems of toxicity: “adaptation of these techniques to aerial application of the herbicides would be difficult to rationalize at the present time, but if and when winter or dormant treatment can be adapted to aerial application you will have not only an expanded field of operation but a much needed extension of your operational season."[28]

Aerial applicators did recognize some general principles when spraying 2,4-D in rangelands, croplands, and pastures, however. As the *Air Applicator's Informational Handbook* so aptly instructed pilots in 1951:

> 2,4-D is one of the most critical sprays because only minute amounts can injure many broad leafed crops. Examine the adjoining fields and make sure that drift is not going to do damage to an adjoining crop. If there are vulnerable crops use extra care when approaching field boundaries watching wind directions and velocities accurately. The amount of cross wind which can be tolerated will depend upon the altitude at which the 2,4-D is being sprayed. Lower spray pressures and coarser droplets help to minimize drift. Cotton, peas, tomatoes, grapes beans and ornamentals of the plants can be easily injured by 2,4-D.[29]

Pilots could significantly reduce the risks associated with 2,4-D, the *Handbook* noted, if they followed some simple precautions. First, pilots needed to use diluted sprays of sodium and amine salts as a mixture with the herbicide. This mixture process balanced the herbicide, keeping it from a pure toxicity. Both types of salts also helped manage the rate of absorption once the 2,4-D spray began to interact with weeds. Second, pilots ought "to use the lowest pressure and nozzle capacity possible for efficient spraying." This tactic not only kept costs low but it increased the selective ability of the herbicide—this was part of the low volume spray trend that began in the early 1950s but really took off in the 1960s (see Tables 2 and 3).[30]

Other rules governing the application of 2,4-D, according to the *Handbook*, espoused pilots to use the "the smallest possible dosage consistent with effective weed control," to "spray downwind of sensitive crops," and "to spray at the time of wear when the susceptible plants are in their least sensitive stage." Dosages too high and applied recklessly meant certain crop death and quite possibly public health hazards due to drift. Chemical applications that were too low only allowed pests to continue their injurious expansion into the fields, pastures, and ranges of the Great Plains. Finally, the *Handbook* reminded pilots that even these precautions were not "entirely foolproof. If they could not be followed, *do not use 2,4-D weed killers near valuable sensitive plants*."[31]

In a similar way, Stahler's survey identified a host of other technological adaptations that pilots made to their spray planes and the growing problems of aerial application in the region. Light, agile, and accurate were the catch words, Stahler said, in the "universal favoritism developing for the light ninety horsepower, monoplane of the Cub or Aeronca type as replacing the earlier favored war surplus Stearman biplane." These new models, unlike their wartime predecessors, could easily adapt to the ever changing chemical-agricultural landscape, which meant lower operation costs and safer pesticide dispersals. Also, the turbulence associated with biplane trainers created an ineffective pattern prone to drift, Stahler remarked. Lighter monoplanes, on the other hand, could be operated at much lower altitudes with a controllable "tree-nozzle" pattern that can pinpoint weedy foliage, avoiding crops and livestock nearby.[32] Stahler also believed that new advancements in boom design needed to follow the characteristics of chemicals and the region.

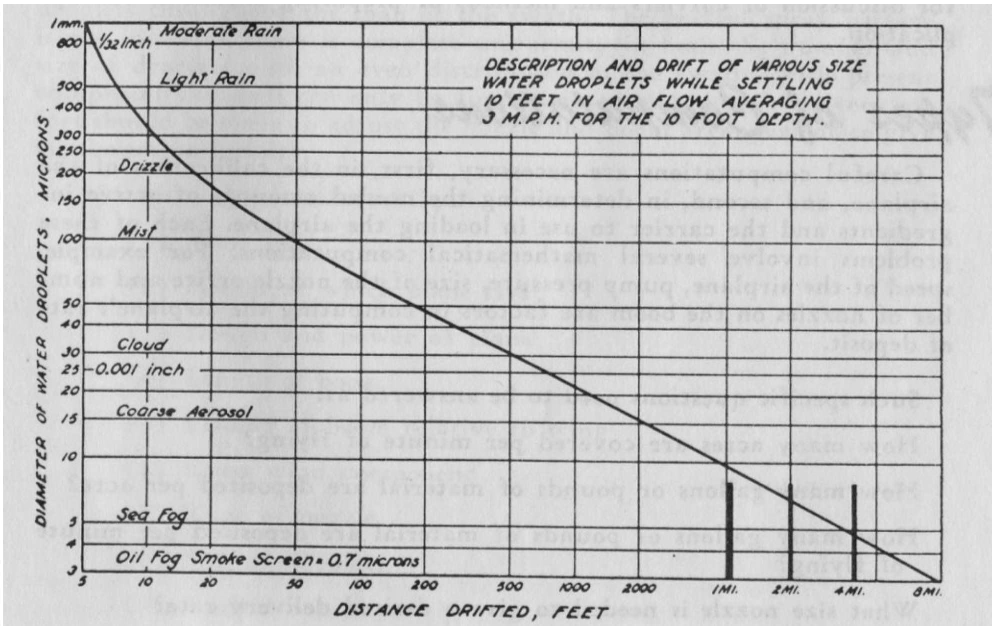


Table 2. An example of a 2,4-D Aerial Spray Chart. Reprinted from *Air Applicator Information Series* (Volume 3), 9.[33]

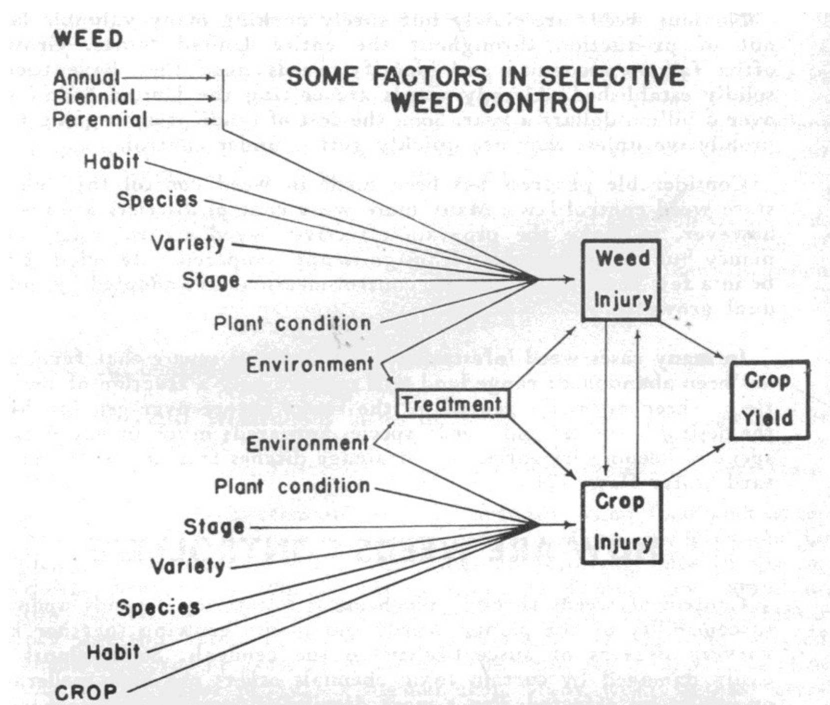


Table 3. "Some Factors in Standardizing Aerial Application of Herbicides." Reprinted from *Air Applicator Information Series* (Volume 2), 52.

Most plane spray operators indicated that “newer booms and light widely spaced nozzles” are almost without exception “superior to the older, heavier type of boom with many close spaced nozzles. One…operator…indicated that he had, as a result of his experimental work, about decided to convert his booms to closely spaced nozzles of low volume as he believed he secure more throughout and uniform spray coverage with the latter type of equipment.”[34]

The need for accuracy reflected more than the economic costs that came with willy-nilly spraying. Pilots had to learn to follow the toxic principles of the pesticides and the vectors on the ground. Damage to crops and chemical residuals in the soil placed farmers and community leaders on high alert, but just as dangerously, as Stahler pointed out, was that hazards encouraged a bias against farm chemicals. The low accident rates of Ag pilots and minimal crop damage related to aerial spraying reflected the fact that pilots “have been conservative, exceedingly careful and highly aware….We had a large number of pilots operating in 1949 that had no previous spray experience. We can only conclude that the aerial spray schools and short courses…have paid real dividends in the accomplishment of the pilots who sprayed 2 ½ million acres in 1949.”[35]

Yet local prejudices still abounded. Too many pilots could operate under their own standards and techniques using a guise of expertise as a marketing ploy for their services. These “thistles” in the industry were dangerous because they clearly represented the deadly risks of farming the chemical way. Stahler did acknowledge that the first decade of the postwar era had produced a significant amount of aerial application advancements. But looking at the 1950 season, the industry still required a tremendous amount of policies and protections to coincide with the hazards, both perceived and real, that the public felt toward aerial operators. However, he told his audience that they were too inept and too dismissive when it came to some of the most significant risks. The main objective weakness "in aerial spraying development as indicated by the data which I have gathered, is the lack of intrastate and interstate organization for protection of your new industry through the establishment of a uniform code of ethics, legislation and financial protection. Aerial spray application of herbicides has developed like [the weed] Topsy, 'it just growed.'"[36]

Many states, due to the damage of some haphazard pilots, restricted agricultural aviation rather than regulating it. According to Stahler, "aerial application of herbicides is practically barred from certain states and areas where fear of spray drift and lack of confidence in this method of application has developed a spray program based almost entirely on ground driven equipment."[37] Essentially Stahler tried to articulate what farmers expressed—that chemical risks were reduced if applicators controlled dispersal, swath, and mixtures.

Ag pilots had to change this trend. As the USDA representative put it, most pilots had virtually no "well founded data available on most efficient spray swath width; on most efficient concentration of spray solution; most efficient type of spray plane and equipment and other factors concerned with aerial application of herbicides, to establish or refute arguments used for or against the practice."[38] As a result, Stahler maintained that many Great Plains states were creating restrictive legislation that stressed only local observations and local prejudices instead of sensible laws that addressed the risks.

This combative endorsement emphasized the continuing worries of farmers, agriculturalists, and pilots about both the economic and environmental risks of chemical agriculture. While Stahler admitted that he often fell out of favor with many of the region's pilots, most shared his sentiment that for their aerial application industry to thrive, safety of the land and its producers was equal to the destructive forces they could bring to pest populations. Control, selectivity, and knowledge of toxicity in chemical application and pest populations—not eradication—had to be the operating principle for aerial sprayers.[39]

Others at the 1949 meeting confirmed Stahler's findings but not necessarily his retorts. Iowa State College weed scientist E. P. Sylwester, for instance, praised Stahler's recommendations for increased knowledge, training, and public relations. He did not, however, agree that pilots were ill-equipped or necessarily contributing to local prejudice. Rather, he acknowledged that ambivalence came from a legitimate source—the dangers of chemicals. Knowledge and preparation were crucial in overcoming farmer or policymaker reluctance. In Iowa, Sylwester explained, extension weed control was broken into three primary phases that focused on "resident teaching in weed control, research in weed control, and extension education in weed control." And all of the residents living in the selected counties were involved.

Sylwester reported that in 1949, weed officials held 143 separate district, county, and night school meetings where farmers, agriculturalists, and custom applicators could meet one another, discuss new equipment, chemical mixtures, and problems. Yet testing scenarios were some of the best learning tools. Once farmers participated in trial runs of chemical application, met the operators themselves, and studied the various species of noxious weeds, they were more accepting of sprayers and their chemicals applications. For Sylwester, one of the most important sources of information and influence was local media outlets. The meetings with custom sprayer operators, weed commissioners, and salesmen were all sponsored jointly by the Iowa State Department of Agriculture, the Des Moines Register and Tribune, and the Extension Service of Iowa State College. Their collective endorsement and reporting on topics discussed at each gathering encouraged acceptance of custom operators if they could be sure that these sprayers were safe, accurate, and knowledgeable.[40]

Part of Sylwester's influence in weed control came from a regional reputation that moved well beyond the city of Ames or the state of Iowa. Many farmers in other Plains states respected his knowledge of weeds and chemicals. Numerous landowners requested recommendations on mixtures, technical studies on various noxious weeds, or worries about herbicidal toxicity.[41] Sylwester, along with many other Iowan extension personnel, encouraged a weed control syncretism that merged cultural and chemical applications. Selectivity and safety not only preserved the health of farmers' crops, it kept costs down. He offered a similar argument for custom spraying: "We have had some very unfortunate cases of injury reported in Iowa due to carelessness in the use of weed killing chemicals. We are going to try to do everything in our power to prevent such damage in the future."[42]

When the NCWCC met again in 1950, organizers decided to keep at least one annual panel dedicated to discussing the hazards, problems, and toxic consequences from aerial spraying. The variability of pesticides in the grasslands as well as the diversity of crops for commercial agriculture required a safe, selective, and attentive applicator. Harold Vavra, director of the North Dakota Aeronautics Board and a past chairman of the Agricultural Committee of the National Association of State Aviation Officials, continued to lead the charge that McDonald, Stahler, Sylwester, and others had begun in the late 1940s.

Vavra warned farmers, scientists, and sprayers attending the South Dakota conference against having too much faith in chemicals or their technological offspring. A variety of controls and uniform operating procedures needed to replace the individualized habits of aerial applicators. This emphasis on control and regulation, argued Vavra, "has been brought about not only for the protection of the farmer and the legitimate commercial operator but also for the safety of the pilots and the general public." The making of a chemical-agricultural landscape included an economic and environmental geography that was unlike other areas of the country—it is a region in which "agriculture is highly diversified" and thus poses a more complex set of "problems for the aerial applicator and quite specific problems for governmental regulation which may not necessarily occur in states less diversified." [43] Throughout the 1950s, many farmers, weed scientists, and aerial applicators continued to pursue a plan of standardization and uniformity that could at least attempt to govern the hazardous tendencies that came with chemical agriculture.

Effective marketing of farm chemicals and custom application services had to highlight the same concepts. Annihilation messages alone would not sell product nor instill trust in applicators. Both groups had to merge ideas of chemical effectiveness with concerns of safety, protection, and accuracy. Additionally, a local/regional connection had to be forged between users, salesmen, and sprayers that went beyond messaging. Chemical representatives needed to leave the laboratory for the fields, pastures, and rangelands of the prairie west.[44] Aerial sprayers needed to convince farmers that their services were more economically effective and less hazardous than landowners' own efforts.

Du Pont's "The Story of Farm Chemicals" and other Toxic Fables

As many farmers, weed scientists, and salesmen opened their monthly issues of *Agricultural Chemicals* throughout the late 1940s and early 1950s, they saw a growing advertising and editorial campaign that emphasized chemicals' values in protecting agricultural health and safety as much as ringing endorsements of economic efficiency or calls to combat farm pests. Companies throughout the country as well as businesses based in the Great Plains region stressed ideas of health and protection along with comfort and profit.

Part of their success dealt with an alignment to a long-standing scientific agriculture heritage that was expressed through extension reports and technical studies. Farmers and agriculturalists alike had access to a growing number of measured works that considered the chemical, biological, and economic relationships surrounding production agriculture. As illustrated with the roles of weed scientists such as Iowa's Dutch Sylwester, farmers and custom applicators interacted both professionally and personally with agricultural experts to grow in their knowledge, check on pesticide mixtures, dosages, and pest information. Agriculturalists worked in the fields and pastures of the grasslands, affording them an authenticity with rural residents. Chemical companies like Du Pont, Monsanto, or Thompson-Hayward (Kansas City) focused their advertising in similar ways. Yet making these kinds of connections in technical studies and annual pest reports only went so far. Salesmen had to venture out, get a sense of the region, the people, and the pests to really hold an effective pitch.

Advertisements, technical studies, and trade journals also highlighted the crucial role of farmers and applicators, like those working the grasslands, in national diplomatic efforts. By protecting their fields from insects, guarding their pastures from weeds, and keeping their soils fertile for future planting, chemicals became more than weapons in a Cold War—they represented a "Green Revolution" that was feeding the world.[45]

A third part of the agricultural health and safety message combined the risks, hazards, and localism of chemical farming. Companies, as expressed through numerous editorials in *Agricultural Chemicals* that emphasized dangers while at the same time reminding users about labels and safety, actually benefited sales. This method embraces what consumer historian Liz Cohen describes as "localism." In her study on the politics of mass consumption in postwar America, both the democratic promises and social benefits of consumers had to do with Americans' living locations and surroundings. "Respecting both peoples' needs for housing and the future health of the environment required honest and open balancing of one against the other, not the strategic use of one to hinder the other."[46]

Chemical manufacturers and aerial sprayers both recognized that success demanded regional knowledge, concerns, and problems of chemical agriculture. Localism, in the context of selling farm chemicals or spraying services, meant informing rather than praising; companies struck a balanced message of science, local knowledge, and possible public or environmental hazard rather than keeping those dangers hidden.

These strategies had the desired effect. Farmers could read about the newest synthetic poisons for their fields and obtain enough "application guidance" to keep their enthusiasm for the poisons while at the same time address some of their worries. This was another way to increase user confidence in the product. Acknowledging that farmers were generally enthusiastic about pesticides but feared potency, cost, and hazards became part of the rhetoric, allowing ads and salesmen to minimize the ambiguities. Again the dangers of chemical potency, if heeded, meant preserving agricultural health from weeds or insects, which improved harvests and reduced labor.

A crucial tactic for periodicals like *Agricultural Chemicals*, then, was describing chemical and application advancements across the country. Of course, many such listings and technical summaries focused on the Great Plains region, with farmers, applicators, weed scientists, and others describing both the values and hazards of pesticides, especially the local problems of reckless applicators. As early as October 1948, the journal issued warnings that the reckless application behaviors of Ag pilots and farmers in areas like the Great Plains and the South was harming chemical manufacturers and salesmen by mixing and spraying pesticides, dangerously violating "all of the rules of safety and common sense … obvious to every informed operator." This inattention to the dangers of toxicity and labels, insisted the editorial, has sparked a public resentment "toward the use of 2,4-D and certain insecticides, as voiced in state legislatures…and medical groups [and] is causing worry among legitimate custom dusters, sprayers and foggers. They can see their 99 percent good record of sensible application being threatened by the widely publicized errors of an irresponsible one percent."[47]

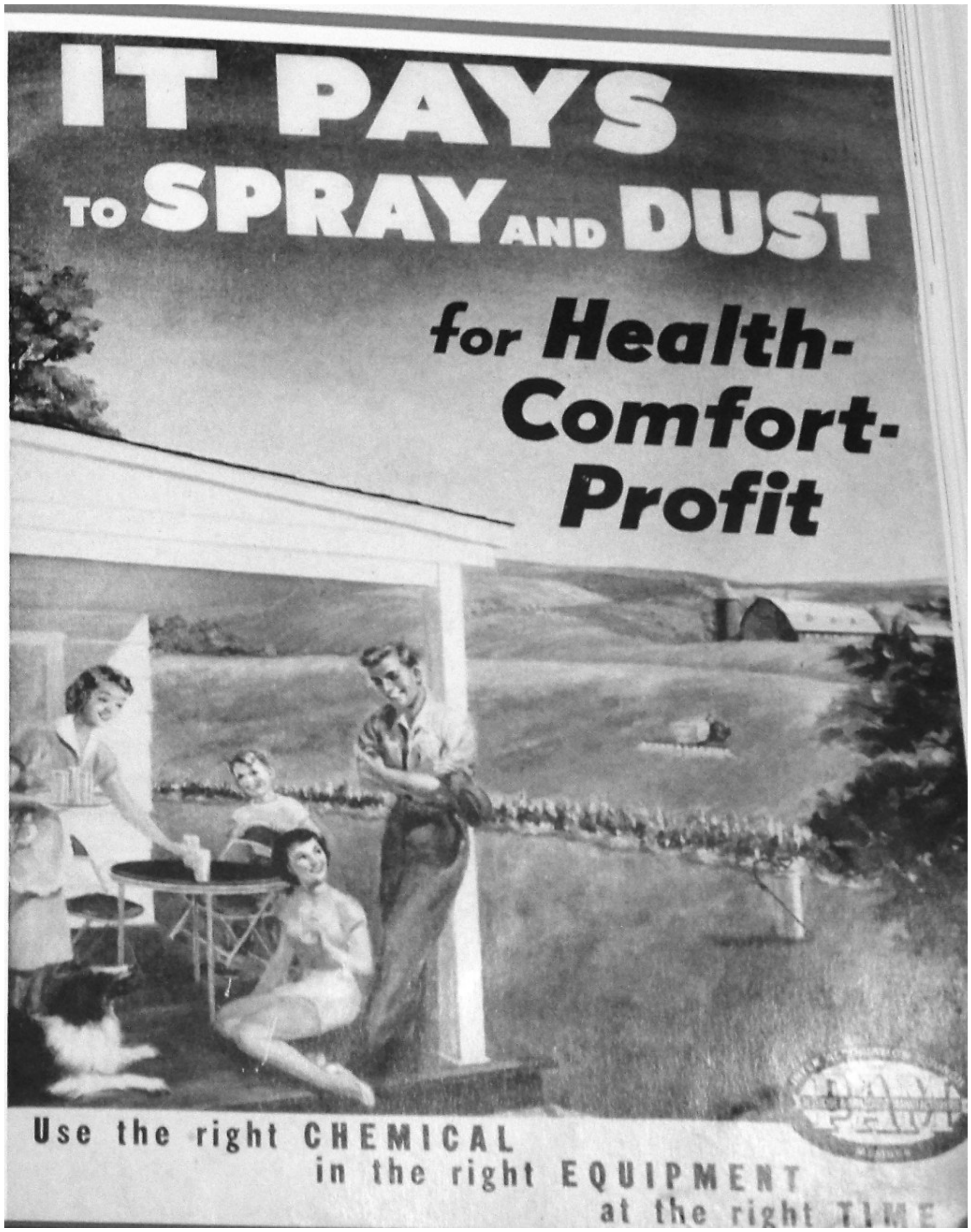


Figure 17. "Health-Comfort-Profit." Reprinted from *Agricultural Chemicals* 9 (March 1954): 1.

Farmers, applicators, and the industry had to eliminate this hazardous "thistle" from the chemical community. According to the journal, indiscriminate application of pesticides by a small reckless minority posed risks that hurt crops, users, and reputations and that damaged the future of farm protection:

> What can be done to eliminate [them]? Who are they? Is it possible to spot the ones who may spray 2,4-D on susceptible crops to kill insects? Does anyone who hires a job to be done know how much or how little the prospective operator knows about toxicants and their proper use? How can a farmer know an operator's abilities without first trying him out…with perhaps a year's crop at stake?[48]

By acknowledging the dangers to fields and users alike and linking those with messages about agricultural health, manufacturers hoped to increase confidence and loyalty among its rural consumers. Careless users and application practices were as dangerous as pesticides and manufactures, the journal stressed—"labels mean nothing if they are not read and heeded."[49] Yet, "the manufacturer is too often criticized for the misdeeds of persons who misuse his products."[50] These warnings represented the first of many attempts by the chemical industry to shift blame from their particular brand of poison to the user as a way of acknowledging the risks of chemical agriculture in the face of mounting concerns.

Another form of legitimacy came through self-critique. *Agricultural Chemicals* insisted that manufacturers had to reform their reports on chemical toxicity, potency, and pest ecology to be less scientific and more agricultural. Although professional assessments could assuage landowners and aerial applicators due to their growing relationships with agriculturalists, manufacturers and salesmen still needed to hone their products and pitches to the concerns and standards that the farmer and applicator implemented in the fields, pastures, and rangelands of the region.

Because these principles included environmental as well as economic hazards, chemical sales representatives could not simply speak of their new products as "being 'safer' than other insecticides [or herbicides] for which they [sic] can be substituted," as *Agricultural Chemicals* warned in its March 1951 editorial. While reduced toxicity hazard claims did have "some valid test basis for support…the whole idea of talking 'safety' in insecticide [or herbicide] advertising is all wrong. Though the product described is measurably 'safer', it is still not essentially a really safe material." However, the editorial went even further. The danger of misrepresentation, inattention to the local concerns of the region, and even chemical recklessness were equally the fault of the salesman—not just the reckless applicator or giddy farmer. "It is always dangerous," urged the journal, "to turn advertising and publicity men loose in any technical field, particularly so in the insecticide field, where the only sound course is to lean over backwards on any safety claim, following the policy of super caution."[51] The ability of pesticides to damage crops, hurt agricultural animals, and poison users had to be emphasized in ways that farmers and applicators could understand. Instead of pointing to "meaningless toxicity differences, the industries publicity and advertising should stress the importance of using masks, goggles, respirators, gloves, and every precautionary device available, with all even medley toxic insecticides. Even with non-toxic dusts, there experts point out there is always the hazard of silicosis."[52]

Local agricultural publications followed the national journals. They also included risk and hazard evaluations in their reporting and marketing materials. *Wallace's Farmer*, for instance, published warnings about shady applicators and pesticide potency. A 1951 editorial advised Iowans to look out for dishonest contracts from unknown pilots:

"Maybe you hired somebody to spray your corn field from the air last year. Many farmers did. Perhaps you're planning on having air spraying done this year. Corn borer losses may have scared you into it…. But there is a risk for farmers here."[53] Farmers needed to "look out for salesmen who will try to talk you into signing the wrong kind of airplane spraying contract."[54]

The editorial suggested landowners be wary of pilots demanding total payment up-front or high down payments. These types of applicators often submitted contracts that allowed them to decide when to spray and dispersal duration rather than the landowner. Other times, pilots used exceedingly vague contractual language about weather and other environmental factors. Nonspecific return times and ambiguous service promises insulated applicators against fulfilling their contracts. It also allowed the applicator to blame other factors if damage, such as drift, occurred.[55]

Regional journals also included discussions on safety, hazard, and suspicion. However, these local papers chronicled the workings of pests and natural toxicity more than the national trade journals. Testimonials by aerial spray pilots and landowners about reckless chemical application and the onslaught of pests on crops, livestock, and soil projected risk assessments alongside glowing advertisements.[56] The emphasis on agricultural health, user protection, chemical selectivity, and toxicity by national and regional journals evolved to fit the transformational forces of the pesticides appearing in the Great Plains.

“Du Pont’s Partnership with the Farmer”

Du Pont Chemical’s marketing materials provide one of the best examples of how chemical companies incorporated the attributes of agricultural science, localism, and hazards. Their advertisements, handbooks, and industry histories all acknowledged the transformative power of pesticides as well as the two versions of toxicity that developed among farmers, aerial applicators, and weed scientists in the Great Plains. The marketing approach of the nation’s premier chemical corporations during the two decades after World War II underscores this regional influence. Du Pont’s slogan “Better things for better living…through chemistry” acquired a new meaning for agriculture and emphasized a new partnership with the farmer as a “customer and collaborator.”[57] In its 1940 booklet “Du Pont’s Partnership with the Farmer,” the company emphasized that its products were increasingly being directed to the agricultural regions of the country and were specialized for the farmer’s needs: “Many [products], however, are primarily for the farmer. As you read in this booklet of the farm products Du Pont buys …what du Pont provides for the farm, we believe you will share our belief that the word ‘partnership’ best expresses Du Pont’s long and important association with the growers of America.”[58] Du Pont’s collaborative stance allowed them to promote their products as tools of protection that increased profits alone or reduced labor. The somewhat basic sections of this particular booklet covered chemicals for seed-treating, fumigation, insecticides, and fungicides. With the cloud of war hanging over the nation, Du Pont articulated a camaraderie with landowners that encouraged the value of “scientific research to the farmer, both in the things he buys and the things he sells” as well as the hazards that landowners endured.[59]

After the war, Du Pont continued its farm marketing campaign through its *Agricultural News Letter*. Beginning in the early 1930s, the *News Letter* included pesticide manufacturing reports, technical reviews, including toxicity studies, and user testimonials. Similar to its contributions in journals like *Agricultural Chemicals*, Du Pont increasingly linked the local worries of pesticide damage, the uncertainty involved with hiring custom applicators, and reports of pest infestations to the potency and promise of their particular brand of poison. By presenting these studies, even works that mildly criticized the agricultural chemical industry, Du Pont could portray itself as the farmer's friend. In the same way they developed new varieties of herbicides and insecticides, the chemical company manufactured empathy with farmers and applicators in regions like the Great Plains. To succeed at this, however, meant that manufacturers had to develop rhetoric, relationships, and products that fit the specific chemical-agricultural landscape. The more often they cited the experiences of farmers, provided updated application information for sprayers, or reprinted new weed science investigations, the more companies had to conform to what producers, pests and poisons did in those places.

These motivations influenced the publication of the company's 1953 trade booklet "This is Du Pont: The Story of Farm Chemicals." In the opening leaflet, Harold Brayman, Director of Public Relations, constructed a history of farm chemicals that incorporated the heritage of agricultural science, the larger diplomatic role of American agricultural production, and the localism that acknowledged the danger of pesticides as well as their benefits:

> Here is a booklet which I think you will find stimulating and thought provoking, where you are closely in touch with the agricultural scene or solely concerned as a consumer of food and fiber from American farms. 'The Story of Farm Chemicals'…pictures the dynamic force of technology, as the power which has

> impelled the most startling era of advancement in American agricultural history. Beyond this, it points to the practical approach, through research and improved knowledge of nature's processes, which can help solve the problem of feeding the world's millions.[60]

Steeped in agricultural excpetionalism, Du Pont's tale of farm chemicals placed pesticides on equal ground to the farmers using them. The poisons that protected fields, proclaimed DuPont, not only brought fruitfulness through preserving and improving yield health but also systematically transformed the agricultural landscape to be more productive—something older technologies and mindsets never achieved. In essence, chemicals provided a conservation of the soil by protecting it from pests and keeping it fertile for a rapidly growing national and global population: "The most important—and stubborn—facts confronting the farmer today are: 1) the acreage of the world on which his crops grow is surprisingly small; and 2) the prospects of adding to it substantially are remote…. Admittedly, heroic and costly conversation, reclamation and irrigation projects can add some acreage, but this will extend our arable area only a fraction. The solution lies in achieving better results in food crops and animal products from the land we now farm."[61]

Expanding the linkages between chemical protection and "balancing nature" by removing those plants, insects, and diseases that constantly threatened the fields, pastures, and rangelands elevated farmers and their chemical "companions" to a status of conservationist—producers were not merely using the land to make money; they were helping preserve the soil, animals, and crops in ways that the biological community failed to provide.[62] Overcoming the "ravages of nature," as Du Pont's story put it, came through careful and selective chemical application—while unseen, pesticides worked alongside farmers to return a balance and health to their lands:

> Here, the chemical industry has made notable contributions. Its products enrich the soil and the crops; they strike back at the insects and pests which plague the farm animals and crops; they limit the crippling effects of animal and plant disease; they attack and kill predatory weeds; they improve the diet and health of our farm animals. And they insure the farmer's investment and the nation's food supply.[63]

A central part of Du Pont's marketing ploy was to present chemicals and those applying them as the physicians of the fields. Yet as with medicine, there were risks involved and hazards to avoid. But failing to apply these unseen, synthetic doctors also allowed other, more nefarious "criminals" to destroy farmers' lands.

Identifying pests as vectors of toxicity over the dangers of pesticides allowed companies like Du Pont to connect to the evolving farmland toxicity standard emerging in the Great Plains. In a section titled "Weeds are Criminals," for example, Du Pont described the rogue plants as the lowest criminals of the plant world with four main methods of attack: "The Smotherer, The Sneak Thief, The Strangler, and The Poisoner."[64] The first group carried out "its nefarious activity by growing faster than food crops and blotting out needed sunlight." Farmers had to stay vigilant and spray at the first sign of infestation. Weeds in the "Sneak Thief" category primarily utilized their roots to kill crops. This type of plant "needs more food than crops" so it "sends out more roots wider and deeper" to steal "nourishment which should go to the useful crops." The third group consisted of stranglers that twisted and wound themselves up and around "useful crops, such as corn, until by sheer weight and food theft, it kills off [the] unhappy victim." The final group "such as locoweed and others, contains noxious chemical substances that are very harmful to cattle which may happen to use it for forage."[65]

Du Pont's tales of poisonous weeds, chemical physicians, and heroic farmers reveal important linkages to how pesticides, pests, and producers interacted within regions as much as they point to larger national and international significance. Certainly the American diplomatic enterprise to feed the world through a "Green Revolution" was a factor, but the ability of pesticides to shape and reshape the American agricultural production had much to do with the changes and adaptations occurring in regions like the Great Plains.

Although connecting all farmers to a greater calling—that of feeding the world—worked to a point, linking their sales pitch to a specific region gave Du Pont access to a language and an ethos that increased the marketability of their products. Put another way, manufacturing pesticides for farmers was simply not enough. Companies had to speak a language and project an understanding of local problems, tools, and experiences. Du Pont emphasized conservation, hazards, and toxicity that closely followed the transformations occurring in the Great Plains. And throughout the 1950s, many other national companies like Dow or Monsanto as well as regional businesses such as Thompson-Hayward used similar marketing ploys.

Selling and Contracting at the North Central Weed Control Conference

Another method employed by chemical companies to gain a regional edge was to attend conferences like the NCWCC to meet with farmers, custom applicators, and agriculturalists. For salesmen and aerial applicators, local and regional connections provided them the social potency they needed to convince users toward their particular brand of pesticides and spraying services. Similar to its contribution to the standardization of regional aerial application, the NCWCC provided a venue for manufacturers and custom applicators to learn the language of farmers and experts, debate their concerns, and cultivate strategies to devise marketing plans that better suited Great Plains agriculture and how pesticides were changing it.

In the 1948 and 1949 meetings, many panels discussed the growing relationships between chemical manufacturers, farmers, Ag pilots, and pesticides themselves. Following Ag pilot O. K. Heddon's presentation of the factors associated with applying herbicides with aircraft, W. C. Dutton from Dow Chemical gave a paper to address the "industrial viewpoint" on pesticides and to respond to the growing critiques and distrust among landowners and applicators toward agricultural chemical manufacturers. He began by immediately emphasizing his regional and agricultural "credentials":

> I worked for 23 years on the staff of a state experiment station and during most of that time was studying the use of a few of what we now call agricultural chemicals. Early in the that period the list of such chemicals was very small and consisted almost entirely of fungicides and insecticides, mostly inorganic compounds, but the list has grown rapidly in recent years and you may ask, 'where did they come from and how were they developed.' Twenty five or thirty years ago the usual procedure was for the manufacturer to send a new product to some Experiment Station worker and asked him to test it. Few manufacturers in those days had facilities for thorough development of new products.[66]

Dutton acknowledged that while the newer, more potent pesticides are promising in the laboratory, they can still present serious problems in the local environment that were unanticipated or unseen in the lab. Often the hazards, as farmers and applicators were well aware, came with the wetting agents, emulsifiers, or solvents that were added to the original product to control potency or to restrict drift. These additives could actually increase the toxic outreach of insecticides and herbicides in fields or pastures rather than controlling them.

Dutton attempted to subtly shift blame to users rather than manufacturers. He told the crowd that negative views toward chemical companies reflected unfortunate rumors. The tension between laboratory promises and field performance or that manufacturers were reckless, profit driven, and often ignored the possibility of hazards were simply not true: "I can say very honestly that I have had no regrets for having made the change for the very good reason that I have found that the research program of industry is just as sound and well directed as that of any public institution. We are told in our work with agricultural chemicals to 'get the facts, no matter what they are or whether we like them or not.' Research is the background for most sales programs and no sales program can proceed for very long if it is not on a sound basis."[67]

To legitimize his claims, especially that Dow should be a trusted ally in chemical agriculture, Dutton identified some of the "special problems" that occurred when farmers or sprayers used pesticides. From life-span and selectivity issues to supposed rapid-fire marketing campaigns or the ongoing problems of home-made mixtures, he claimed that the chemical industry sought uniformity, standardization, and reliability in their procedures and tactics. Again, he shifted responsibility to users, insisting that manufacturers guarded their formulas and trials from workers until they were safe, effective, and profitable. Instead, overzealous farmers and applicators were to blame: "Users may build up unjustified hopes in what a product will accomplish and Industry is embarrassed and sometimes put to considerable inconvenience and expense to inform inquirers that it does not have the product, doesn't know anything about or is not ready to recommend it for use."[68]

At the 1949 Sioux Falls meeting, agriculturalist James Montgomery expanded these strategies to aerial application, recommending that Ag pilots understand the regional nature of chemical use. Landowners were often skeptical upfront, he reported, but as applicators landed spraying contracts with surrounding farms, showed that they could keep costs down, accuracy high, and fields safe, their contracts would increase. Proof, selectivity, and adaptation were central to an Ag pilot's success. According to Montgomery, what sprayers really needed in the 1950s, was "actual proof rather than a lot of talk, and figures on paper that show the advantages which the farmer might gain."[69] Ag pilots needed to align their costs, services, and abilities to the behavior of chemicals, pests, and the fields they were treating. "If a job is done right, the proof is before their eyes and they will certainly fall in line with one of the greatest scientific strides that agriculture has ever made."[70]

Montgomery urged pilots to place advertisements in farm journals and secure radio spots to market their chemical, pest, and flying expertise. However, more important than advertising, he insisted, was providing technical and testimonial materials that spoke of the ecological workings of chemicals in ways farmers could understand. Farmers needed to read reports about pesticide-plant interactions, review studies about soil residuals, and view accuracy statistics of the Ag pilot. They needed to hear about the safe success of other farmers. These "stories" allowed customers to observe how chemicals worked in their fields and how applicators adapted their techniques and spray planes to their particular field, pasture, or rangeland. Montgomery also encouraged recognition of the dangers and risks associated with aerial application. Honest assessments of the hazards elevated the professionalism of the Ag pilot because "the more scientifically it is explained by an operator, the more readily it will be adapted. Explain that it is not as dangerous as many people are led to believe, that the pilots are all experienced and experts in their line and that it is in no way an air show."[71] Adaptation, selectivity, and toxicity were factors in a pilot's ability to acquire spraying contracts and build a successful business. Their greater conformity of messaging, tools, and relationships to the workings of pesticides allowed pilots to increase their profits and reputations.

Throughout the 1950s, NCWCC meetings continued to reflect these types of exchanges. Debates over potency, pest resistance, and selectivity allowed both manufacturers and applicators to refine their pitches and promises to follow the changes taking place throughout the region. Dutton's analysis at the 1948 meeting and Montgomery's in 1949 as well as the numerous panel discussions in the 1950s underscore how manufacturers and aerial applicators' marketing strategies and pursuit of standardization followed patterns and used rhetoric specific to the chemical-agricultural landscape in the Great Plains.[72]

The technical, environmental, and procedural changes that occurred in the late 1940s and early 1950s all represent the transformative power of farm poisons. Along with these user and tool varieties emerged an agricultural-chemical landscape expressed in farm journals, technical studies, and industry material that reflected the ecological and technological changes taking place in the Great Plains over two decades after World War II. For companies like Du Pont and Dow Chemical or regional businesses like Thompson-Hayward and the expanding network of aerial spraying outfits to succeed in the agricultural chemical business, they had to adapt to the consequences of chemical farming rather than just simply proving that their new product could kill insects and weeds better and faster than the older insecticides or herbicides. Ag pilots also relied on local knowledge of pests, the variability of crops, and environmental conditions of the regions. Manufacturers, sellers, and sprayers could not simply sell annihilation—they had to be honest about the risks, present accurate mixture-rates, reinforce label standards, and perhaps most importantly, "get dust on their boots."[73] Protecting abundance had as much to do with convincing the farmer that their fields would be safer, healthier, and thus, more productive as with reducing labor or increasing outputs through chemical death.

By combining safety, accuracy, and professionalism with pest control messages, chemical companies and aerial spraying firms helped formalize the standards landowners, pilots, and agriculturalists would hold regarding toxicity and risk when spraying their fields. However, in the aftermath of Rachel Carson's 1962 *Silent Spring*, this vision would have to adapt to national politics and regional realities that increasingly placed pesticides, aerial sprayers, farmers, and weed scientists into simplistic political distillations—environmental health evolved to mean something different than agricultural health.

Notes

[1] "Knowing Agricultural Chemicals" *Air Applicator Informational Series, Volume 1* Minden, Nevada: Agricultural Aviation Academy, [copyright 1951; revised 1964 and 1965]), 54.

[2] *Proceedings* (December 1949), 92.

[3] See Dawn Biehler, "In the Crevices of the City: Public Health, Urban Health, and the Creatures We Call Pests," PhD diss., University of Wisconsin—Madison, 2007. ProQuest (AAT 3294117).

[4] This description was specifically used for Parathion in the *Air Applicator's Handbook*. It warned that a growing number of producers and experts viewed this specific insecticide as a terror chemical: "Here is an insecticide being viewed with terror by some people because of its high toxicity to man. When used properly there is no more danger than there is in handling many other poisons. You *must* understand its characteristics, however, namely that it has no odor and therefore can be breathed without detection. See "Knowing Agricultural Chemicals," *Air Applicator Information Series*, Volume 1 (Minden, Nevada: Agricultural Aviation Academy, [copyright 1951; revised 1964 and 1965]), 32–33.

[5] David Kinkella, *DDT and the American Century: Global Health, Environmental Politics, and the Pesticide That Changed the World* (Chapel Hill: University of North Carolina Press, 2011), 114. Kinkela explains that during the *Silent Spring* Era, the debate over pesticides hardened into two opposing camps: "one that valued the effectiveness, the low cost, and the low toxicity of DDT, and one that viewed the chemical as an environmental contaminant on a global scale."

[6] See "Knowing Agricultural Chemicals" *Air Applicator Informational Series, Volume 1* Minden, Nevada: Agricultural Aviation Academy, [copyright 1951; revised 1964 and 1965]), 48. For example, the *Handbook* described two primary types of herbicides in use by applicators: *Contact Herbicides* and *Translocated Type*. Contact herbicides are "compounds which 'burn' off all above-ground growth simply by destroying the plant cells with which they come in contact. Except for hardy perennials, the damage to the plant caused by the contact herbicide is so great that the root dies as well. Translocated type weed killers are compounds which are absorbed by the foliage or roots and are spread throughout the growth. Translocated type herbicides cause the entire plant, including roots, to die." For more on some of these concepts also see Chapters 2 and 3.

[7] Historian Edmund Russell demonstrates wartime rhetoric in domestic pesticide marketing. See *War and Nature: Fighting Humans and Insects with Chemical from World War I to Silent Spring* (New York: Cambridge University Press, 2001); Idem., "Speaking of Annihilation": Mobilizing for War against Human and Insect Enemies, 1914–1945" 82 (March 1996): 1505-1529; Idem., "The Strange Career of DDT: Experts, Federal Capacity, and Environmentalism in World War II," *Technology and Culture* 40 (1999): 770–796. However, while I acknowledge the influence of war in the rhetoric, this dissertation joins historians David Kinkela (*DDT and the American Century*) and Kendra Smith-Howard ("Perfecting nature's food: A cultural and environmental history of milk in the United States, 1900—1970" PhD diss., University of Wisconsin—Madison, 2007 ProQuest [AAT 3278896]) in arguing that health, protection, and hazard were also forces in shaping environmental and cultural landscapes in postwar agriculture.

[8] L. L. Coulter, "From Test Tube to Airplane Operators," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 42.

[9] "Table of Contents," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949).

[10] This phrase originally comes from Edwin Way Teale in his 1945 *Nature Magazine* article on DDT: "Given sufficient insecticide, airplanes and lackwit officials after the war, we will be off with yelps of joy on a crusade against all the insects [creating a] conservation headache of historical magnitude." See Edwin Way Teale, "DDT," *Nature Magazine* 38 (March 1945), 120.

[11] W. P. MacDonald, “Spraying Equipment for Herbicides and Other Methods of Application,” *Proceedings* (Springfield, Illinois: December 8–10, 1948): 158–159.

[12] Ibid.

[13] Ibid.

[14] Ibid; this same dilemma would shape the messaging and pesticide varieties that came from chemical companies throughout the decade.

[15] Ibid.

[16] Ibid. 159.

[17] Ibid.

[18] Ibid; Oral History Video Interview with Kansas Spray Pilots, by the Kansas Agricultural Aviation Association, unpublished, author's personal collection (KAAA Conference, Hutchinson, KS: precise date unknown, c. 1990s).

[19] Ibid. MacDonald, *Proceedings*.

[20] Ibid.

[21] Ibid., 164. McDonald’s recommendations would ultimately come to fruition in the 1980s with pilots incorporating Global Positioning Satellite receivers and participating in Operation S.A.F.E. fly-ins. See Chapter 6 for futher analysis.

[22] L. M. Stahler, “The National Picture in Aerial Spraying for Weed Control in 1949,” *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 37–38.

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] Ibid.

[28] Ibid.

[29] “How to Spray and Dust,” *Air Applicator Information Series*, Volume 3 (Minden, Nevada: Agricultural Aviation Academy, [copyright 1951; revised 1964 and 1965]), 8.

[30] Bob Bunker, “Let’s Clear the Air About Aerial Application,” *Kansas Farmer*, 16 March 1968.

[31] “How to Spray and Dust,” *Air Applicator Information Series*, Volume 3 (Minden, Nevada: Agricultural Aviation Academy, [copyright 1951; revised 1964 and 1965]),8.

[32] L. M. Stahler, “The National Picture in Aerial Spraying for Weed Control in 1949,” *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 37–38; “How to Spray and Dust,” *Air Applicator Information Series*, Volume 3 (Minden, Nevada: Agricultural Aviation Academy, [copyright 1951; revised 1964 and 1965]),8.

[33] Original chart duplicated from F. A. Brooks, "Agricultural Engineering," June 1947.

[34] Ibid., Stahler, *Proceedings*.

[35] Stahler's ties to the USDA and the national push of the ARS (Agricultural Research Service) shines through here. As historian Pete Daniel so aptly put it in *Toxic Drift*: "The quest to destroy pests unfortunately outran research on insect resistance, ignored collateral environmental damage minimized the dangers of residue accumulation, and downplayed threats to fish, wildlife, domestic animals, and most importantly, to humans…. Seduced by the notion that farming should be primarily a business and not a way of life, USDA bureaucrats dreamed of capital-intensive farm units that utilized the latest science and technology. Like demented physicians, ARS administrators prescribed chemicals indiscriminately, usually without full knowledge of the target pest and seldom with any thought of side effects. (4–5). However, Stahler's survey also shows that those who worked in the region were forced into much more accurate portrayal of the consequences of pesticides. The larger push to marginalize the hazards for the benefits of chemical application may have been more obvious and deliberate at the federal level, but Stahler's critique of Ag pilots, his concerns about how 2,4-D interacted with crops and the surrounding environment suggest that indiscriminate chemical descriptions were more of a challenge at the regional/local level than with national programs. Also see David Kinkela's chapter "The Age of Wreckers and Exterminators," in *DDT and the American Century* (Chapel Hill: University of North Carolina Press, 2011), 84–105.

[36] Ibid., Stahler.

[37] Ibid.

[38] Ibid.

[39] To conclude his remarks, Stahler tried to come back from his reprimand of Ag pilots: "Among the questions asked in my survey questionnaire was: Do spray plane pilots know weeds and weed control, crops and crop tolerance to herbicides? This is the only question on which I had no discussion in opinion—all reports indicating that the pilots were poorly informed on these important points. All pilots questioned elucidate this admission of lack of knowledge by the complaint of no source of information or schooling for the men who understandably have not had this training. As all Agricultural Extension and research people responded as did the pilots to this question it becomes apparent that we are criticizing aerial spray operators for a fault that it is our responsibility to correct and that I am using time on this program that the pilots would rather have devoted to weed identification and a discussion of reaction of crop plants to herbicidal sprays (41)."

[40] E. P. Sylwester "Extension Weed Control in Iowa," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 22-23.

[41]E. P. Sylwester to B. M. Billings (Missouri), 5 August 1952; E. P. Sylwester to Cora B. Allender (Kansas), 29 October 1952, Box 5, Folder 3; Sylwester to Ray Goodloe (Kansas), 29 June 1953, Box 5 Folder 4 in the E. P. Sylwester Papers [RS9/18/51], Iowa State University Special Collections, Parks Library, Iowa State University. In Sylwester's "Open Forum" that he prepared for the *Des Moines Sunday Register*, circa 1951 links farmer's concerns about aerial spraying and the problem of spray fumes from 2, 4-D: "First of all, let us set out the difference between injury from spray 'drift' and spray 'fumes.' Let me state at the outset that this problem of spray 'drift' and spray 'fumes' is present whenever any herbicide of any type used. Remember that all herbicides are made to kill plants. The chemical has no built in 'radar' or 'sonar' system that tells the chemical what plants to kill and which not to kill. This is true whenever you use one of the commonly available and commonly used weed killers. Thus it becomes of utmost importance that the operator know the good points and bad points of the chemical he is using and practice good judgment in choosing and workmanship in application of the chemical. This responsibility rests on him alone and completely. You have all seen…an airplane spraying or dusting crops...on windy days when the 'drift' of the material is very obvious. This is 'drift.' It occurs at time of application…. Every single one

of the herbicides on the market, not only 2,4-D, but all of them, must be applied with the utmost caution because any 'drift' to other desirable plants, due to obvious inattention to details by the operator, either to other susceptible plants of his own, or those of his neighbors is likely to be highly injurious. Thus, the application of herbicides is an ultimately more difficult task to perform than is limestone, fungicide, or insecticide application. What if these do drift? Who cares? We have grown careless in such applications...[.] (1–2)."See "Open Forum," Box 5, Folder 6, in the E. P. Sylwester Papers [RS9/18/51], 1–7, Special Collections, Parks Library, Iowa State University. For more on Sylwester and the history of agricultural chemical use in Iowa see Joe Anderson, *Industrializing the Corn Belt*.

[42] Sylwester "Extension Weed Control in Iowa," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 23.

[43] Harold G. Vavra, "Standardization of Regulation for Aerial Sprayers in the North Central United States," *Proceedings* (Milwaukee, Wisconsin: December 12–14, 1950), 37.

[44] *Journal of Agricultural Chemicals*, June 1946.

[45] The "Green Revolution" was part of the United States's larger socioeconomic strategy during the Cold War. Technological advances in agricultural production, especially pesticides, were employed in developing nations with the hopes of overcoming famine and financial crises. However, the negative environmental consequences, according to many historians, far outweighed the positives. For more on the history of the Green Revolution see Kirkpatrick Sale, *The Green Revolution: The American Environmental Movement, 1962-1992* (Hill and Wang; Critical edition (July 1, 1993); Lester Russell Brown, *Seeds of Change: The Green Revolution and Development in the 1970s* (New York: Praeger, 1970); Kenneth Dahlberg, *Beyond the Green Revolution: The Ecology and Politics of Global Agricultural Development* (New York: Plenum Press, 1979).

[46] Liz Cohen, *A Consumer's Republic: The Politics of Mass Consumption in Postwar America* (New York: Vintage Books, 2003), 254.

[47] *Journal of Agricultural Chemicals*, October 1948, 19.

[48] Ibid.

[49] Ibid.

[50] Ibid.

[51] *Journal of Agricultural Chemicals*, March 1951, 31.

[52] Ibid.

[53] *Wallace's Farmer*, 1 April 1950.

[54] Ibid.

[55] Ibid. The editorial concludes with some methods of protection: "There are plenty of reliable people in the spraying business. This applies to both ground and air spraying concerns. But be sure the contract protects you. When anybody comes around to sign you up on a contract for spraying your corn, watch these points: (1.) Make sure the contract says that you, not the sprayer shall choose the time to spray. (2.) If you make a down payment, see that it is held in safe keeping (escrow) in a good bank until spraying is carried out. If spraying is not done, the down payment should automatically revert to you. (3.) Cut out this editorial so you can read it again when a contract is presented. We protected you in a similar way in our issue of January 15, 1949. (4.) If you are in any doubt as to the contract you are asked to sign, see your lawyer before you put you name on it. A small legal fee may save you money.

[56] Wallace D. Inman, "The Role of the Farm Press in Better Weed Control," *Proceedings* (Winnipeg, Canada: December 9–11, 1952), 50. Some examples include: "Chlordane Dusts and Sprays," *Kansas Farmer* 16 July 1949; "Thompson-Hayward's Ded-Weed," *Kansas Farmer* 18 June 1949; "Sherwin-Williams' Agricultural Weed-No-More," *Kansas Farmer* 1949; "Pyrenone Wheat Protectant," *Kansas Farmer* 4 November 1950; "Marlate by DuPont," *Wallace's Farmer* 21 April 1951; "Mansanto's New weed and brush killers [2,4-D and 2,4-T]," *Kansas Farmer* 5 March 1956; "Pyrenone Wheat Protectant," *Kansas Farmer* 4 November 1950.

[57] E. I. Du Pont De Nemours & Company, "DuPont's Partnership with the Farmer," (Wilmington, Delaware: Du Pont & Company, 1940), 2.

[58] Ibid.

[59] "New Booklet-Du Pont's Partnership with the Farmer," *Agricultural News Letter* 6.3 (May-June 1940), 48.

[60] Harold Brayman, "Introductory Leaflet," *This is DuPont: The Story of Farm Chemicals* (Wilmington, Delaware: Du Pont & Company, 1953), insert page, Othmer Library, The Chemical Heritage Foundation, Philadelphia, Pennsylvania.

[61] Ibid.

[62] References to Kansas and other agricultural states in the Great Plains are peppered throughout the publication.

[63] DuPont, "The Story of Farm Chemicals," 11.

[64] Ibid., 21.

[65] Ibid.

[66] W. C. Dutton, "Industrial Viewpoint and New Herbicides," *Proceedings* (Springfield, Illinois: December 8–10, 1948), 168; William W. Allen, "Formulation in Industry," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 45–46; R. L. Brandenburger, "Distribution of Agricultural Chemicals," (Sioux Falls, South Dakota: December 6–8, 1949), 46; Joseph A. Noone, "Seller Responsibility," *Proceedings* (Milwaukee, Wisconsin: December 12–14, 1950), 18–20.

[67] Ibid., Dutton, 171-172.

[68] Ibid. Dutton claimed that Dow and the "chemical industry" in general, contrary to local opinion, did in fact consider these "special problems" that concerned farmers, aerial applicators, and weed scientists. I have included three of his primary points in this footnote that highlight the changes in messaging that followed the workings of pesticides in the Great Plains, but Dutton's other points are also worth investigating. Special Problem 1: Specificity: "Another problem that is serious with Industry, Experiment Stations and users of agricultural chemicals is what we call "specificity." This simply means that a given compound is very specific in its action and will kill or control certain weeds, insects or diseases but not others. This can be a very desirable characteristic, especially with herbicides, provided it does not affect the plant you want to save *but it doesn't always work that way* (emphasis mine). Specificity is very marked with many of the newer organic insecticides and fungicides and you all know much about this in connection with weed killers. This situation makes for a multiplicity of products for manufacturers to make and for dealers to stock, it complicates recommendations by agronomists, entomologists, pathologists and horticulturalists, and confuses the users of the materials. *There probably is nothing that anyone can do about it as that seems to be characteristic of the compounds that are being developed now* (emphasis mine)" (172).

Problem 2: Thorough Trial: "This problem of moving too fast raises the question of how to judge when a product has been developed and tested to the point where it is safe for manufacturers to sell and agriculturists to recommend it for use. Premature release of a product by Industry may embarrass public workers and users but I wonder how many cases there have been where a public worker has developed a procedure of material and made recommendations for its use and Industry has supplied the necessary materials only to have the whole thing backfire when it is put into extensive use. I have in mind a procedure that was developed by a public research worker, was tested for several years in widely separated areas, was recommended for use and the materials were supplied by Industry on the basis of the seemingly thorough trials. *Every one involved had proceeded in good faith but serious complications developed as soon as it went into extensive use simply because, in my judgment, a set of climatic conditions developed that had not occurred during the development period. I could cite other similar instances. The point I want to emphasize is that it behooves public research workers as well as Industry to be very thorough in developing now procedures in order to be reasonably sure of safe use but this takes us back to the question of how shall we judge when a product is ready for release. Climatic factors, nutrient relations and the specificity I mentioned earlier all have a bearing on this* (emphasis mine, 172)."

Problem 3: Home-Made Products: "I think those of us who have worked with agricultural chemicals for sometime can recall that farmers and fruit growers used to mix or make many of the materials they used. Fruit growers used to make liquid lime-sulfur, self boiled lime-sulfur, calcium arsenate, other arsenicals, nicotine extracts, etc. and Extension Service men used to stage demonstrations on home-mixing of fertilizers but I think you would have a hard time finding anyone now who does any of these things…. *The principal reason why these practices have been discontinued is because highly standardized, uniform products are available. With the advent of modern herbicides there has been some talk of using home-made formulations and that is the privilege of anyone who whishes to do so, but I am confident that in the long run most users will find it much more satisfactory to use the uniform, standardized products that are available* (emphasis mine, 172)." (**Author's Note**: As Chapter 5 underscores, these home-made mixtures were part of the rogue pilot's and chemical bootlegger's arsenal—they actually did not end with standardization. Dutton's appeal to farmer/applicator individualism while at the same time pushing uniformity through Dow and other companies is a good illustration of how marketing toxicity and standardizing risk were changing with the chemical-agricultural landscape in the Great Plains).

[69] James Montgomery, "Selling—Contracting—Collecting," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 43.

[70] Ibid.

[71] Ibid.

[72] Wallace D. Inman, "The Role of the Farm Press in Better Weed Control," *Proceedings* (Winnipeg, Canada: December 9–11, 1952), 50; John Burke [Aerial Applicators Association], F. W. Bone [Department of Transport, Civil Aviation, Winnipeg], R. E. Larson [University of Missouri], J. C. Chamberlain [U.S. Department of Agriculture], "Where Are We Headed With Aerial Application," *Proceedings* (Winnipeg, Canada: December 9–11, 1952), 50; John H Burk, "Aerial Spraying and Engineering," *Proceedings* (Oklahoma City, Oklahoma: December 11–13, 1951), 50; Archie Gieser, "The Aircraft and Special Equipment Center," *Proceedings* (Oklahoma City, Oklahoma: December 11–13, 1951), 50; George Childress, "The Civil Aeronautics Administration," *Proceedings* (Oklahoma City, Oklahoma: December 11–13, 1951), 51; W. T. Piper, "Remarks," *Proceedings* (Oklahoma City, Oklahoma: December 11–13, 1951), 51–52; Ralph Young, "Remarks," *Proceedings* (Oklahoma City, Oklahoma: December 11–13, 1951), 52–53; John Burke, "Remarks," *Proceedings* (Oklahoma City, Oklahoma: December 11–13, 1951), 54; 56.

[73] *Journal of Agricultural Chemicals*, June 1946.

Chapter 5: Warnings, Regulations, and the Politics of Poison

Unethical, fly-by-night salesmen and even some local merchants have plagued the 2,4-D business as they have most other lines. In order to cut prices, and in spite of legislation in most states to the contrary, some retailers have ordered 2,4-D in bulk and then poured it out into the farmer's own containers in order to give the purchaser the benefit of the quantity price discount...It has also been true that on many occasions unreliable salesmen operating from their automobile have fast-talked famers into placing substantial orders with them. This has been done with no intention of ever returning to check on the results obtained or to give the farmer any other kind of service…The entire chemical industry must keep in mind that the local dealer is the man on the firing-line and is actually considered by the consumer to represent the entire industry. Anything that can be done by the distributor, the formulator, or the manufacturer to help him with his problems will be beneficial to all.[1]

W. P. McDonald, in "Problems Related to Industry—Sales," *Proceedings of the North Central Weed Control Conference*, 1949.

"Where Are We Headed With Aerial Application?": (1), The agricultural aviation people need help of a technical nature on all phases of their activities, i.e., engineering, chemical, agronomic, and economic. (2) Not all trouble laid to aerial applicators is actually a result of their activities. In one area of eight claims against aerial applicators, five were found on investigation to have resulted from ground application. (3) Unethical and careless operators are being weeded out as a result of competition. (4) 300 accidents with 51 fatalities in 90 days is evidence that further study is needed of operational hazards. (5) There is need for aircraft design research. The Ag-1 is not performing to the satisfaction of many operators. (6) A better system of speedy dissemination of information relative to pest out-breaks where aircraft services are needed would be desirable. (7) Proper regulation to protect all concerned should be set up at the State level.[2]

Summary Panel Discussion at the 1952 NCWCC in Winnipeg, Canada.

Part of adapting to the chemical-agricultural landscape in the Great Plains meant users and applicators needed to understand the dangers of pesticides. These potent tools could be protectors of the fields and guarantors of agricultural health, but they could also become unruly, burning crops, poisoning animals, and ruining soil. During the two decades after World War II, producers, applicators, and weed scientists all praised the possibilities of pesticides, but they also developed certain tools, practices, and standards to protect themselves and their lands. The culmination of these interactions highlighted a farmland toxicity standard that merged hazards of herbicides and insecticides with the destructive traits of pests—users had to think like chemicals and pests to effectively use or control them. To ensure the agricultural health of the landscape required caution, mixture standards, selectivity, and technological uniformity that followed the contours of a chemical-agricultural landscape.

However, pesticides and the mix of producers, pests, scientists, and tools that interacted in patterns specific to them also encouraged a group of reckless applicators and shady formulators at the local level that informed the new politics and policymaking at the national level. Closer to home, these crooked producers, applicators, and salesmen fell under the ire of those following farmland health standards—rogue pilots, chemical bootleggers, and dishonest salesmen were the equivalent to noxious pests. Nationally, however, irresponsible users served as compelling examples for the ecological dangers associated with pesticides. This version of environmental health stipulated that agricultural chemicals and their users could not be controlled, labels did not go far enough, and contamination created long-term ecological destruction.

In response, many farmers, aerial applicators, and weed scientists argued that their regional vision of agricultural health did not ignore the hazards associated with pesticides nor did it overlook the possibilities of long-term residual toxicity in the soil, crops, or dismiss criminal behavior. Better spraying practices, new aircraft designs, drift technologies, educational opportunities, and a balanced regulatory framework all worked, they insisted, to protect farmlands. Risks did exist. Chemicals did not always work correctly or according to their designs. Unruly pilots, shady salesmen, and devious formulators did damage lands and residents, hurting the reputations of even the most attentive pilots. So, environmental contamination was possible. Yet, as the farmland toxicity standard stipulated, for applicators, landowners, and weed scientists, there were also risks in not applying poisons. In this context, Ag pilots, farmers, weed scientists as well as organizations like the NCWCC developed their own precautions that included acknowledging the hazards of pesticides.

This regional ethos of agricultural health and farmland toxicity, which guided farmers, aerial applicators, and weed scientists throughout the first two decades after World War II, also influenced the nationalization of aerial spraying standards in the 1960s and 1970s. From the construction of an "official agricultural spray plane" to the varieties of technical guides and spraying handbooks issued by government agencies such as the USDA and the EPA, the traits of the pesticides—selectivity, adaptation, and toxicity—traveled from the rural airstrips and fields of the grasslands and the exchanges of the North Central Weed Control Conference into instructions for the nation.

The Great Plains, specifically Kansas, also acts as a suitable case study for the era's political debates over pesticides, revealing the social and legal responses to the politics of poison in the *Silent Sprin*g era. The passage of laws, prosecutions of rogues, and toxicity warnings all highlight how ideas about agricultural health changed to fit the era's political and regulatory moves toward pesticide restriction and federal oversight. Also the increasingly caustic exchanges over insecticides and herbicides, especially DDT, sparked by Rachel Carson's *Silent Spring* (1962) helped place the regional version of chemical farm health apart from environmental health. Disputes over pesticides were increasingly cast into simplistic formulas of agricultural efficiency and technological promise versus ecological hazard and indiscriminate poisoning.[3]

Indeed, the national political landscape in the 1960s and 1970s was moving from the chemical age to an age of ecology; farmers, aerial sprayers, and weed scientists would have to adapt. New scientific studies, political views, and regulatory policies of the era challenged their version of agricultural health as no amount of accuracy or uniformity could keep chemicals from accumulating in soils, waterways, animals, and people. At the regional level, farmers, applicators, and scientists responded by expanding their standardization efforts and social networks to conform to new regulatory policies while also continuing to sharpen their commitment to pesticide application for agricultural health. They modified their spray planes, started new spray schools, and endorsed new regulations and technologies that could evolve with pesticides and their environmental, social, and now, political consequences.

Building the Ag-1 and the Federal Endorsement

The standardization impulses of the first two decades of the postwar, as described in Chapter four, culminated with the construction of the Ag-1, dubbed the nation's first "official" agricultural spray plane. The advancements, modifications, procedures, and problems recognized by pilots, critiqued by farmers, and studied by weed scientists worked their way into a federally subsidized program to build a spray plane that was safe, accurate, and economical. This regional influence also shaped federal regulators' recommendations in handbooks, manuals, and policies to govern aerial application in the decades to come.

In April of 1949, Oklahoma's Democratic Senator Elmer Thomas stood up among his colleagues of the eighty-first congress to discuss the rapid advancement of the spray plane. Senator Thomas' farming constituents in Oklahoma, as in many other parts of the Great Plains, saw aerial spraying as a promising evolutionary step in chemical farming, but also identified problems. Determining uniform methods, standard spraying schools, chemical mixture specifications, and legal codes were but some of the challenges coming from this new farm implement. Noxious weeds, invasive brush, and insects also posed drastic dangers that not only reduced field production, but, for Senator Thomas, as with many scientists during the postwar period, the "balance of nature" was tipping in favor of pests; human tools and animal production represented only part of the grassland conservation problem. "Among the most serious problems facing our government today," he proclaimed, "are those relating to soil conservation and restoration. The airplane as a new farm implement will exert a mighty influence in the solution of these problems. Relating this, the American farmer has welcomed the airplane necessary to his operations."[4]

The journal *Aviation Week* had already issued a series of reports on the problematic growth of aerial application. In its February 1949 report on the "Industrial Use of Aircraft," for instance, *Aviation Week* expressed support for the promising trend but issued equally stern warnings about its dangers. The "potential of widespread weed control through aerial spraying and dusting," it stated, "is enormous. It has been estimated that the entire cost of the Marshall plan for one year could be saved by the extra food production in this country which would result from a national weed control effort." However, the article also contested reckless behaviors or even assumptions that anyone could be or should be an Ag pilot. Citing a 1948 bulletin issued by the Civilian Aviation Administration (CAA on "industrial flying, the journal held that "any pilot planning to engage in dusting, spraying, seeding etc. needs: services of an engineer to design the proper apparatus, a chemist, and entomologists and a plant pathologist to determine cause and cure of the problem, and a botanist and the plant pathologist to know what formulas will be effective in individual cases. The farmer owner of the crop must also be completely informed of advantages and limitations."[5] However, the article stood firm about the hazards associated with aerial application, confirming that at the end of the 1940s and early 1950s, most planes remained unsuitable to deliver potent poisons; most pilots were still dramatically untrained.[6]

For Thomas, then, acknowledging the hazards of pests in destroying the landscape required employing chemicals in a uniform and standardized way that incorporated the health of the land and its residents. Profits would follow once these areas were reclaimed for agricultural uses. "Let each of us consider the picture familiar in our minds of the nonproductive farm lands in our respective states. In my fine state of Oklahoma we are unfortunate in having over 10,000,000 of our 35,000,000 acres of agricultural lands rendered nonproductive by the invasion of useless brush. This growth is a result of the disturbance of the balance of nature. Something must be done to solve this problem." Thomas implored his senate colleagues to see chemical agriculture in this way—aerial spraying was a conservation tool, not an eradication method. Selective spraying by a professional spray pilot would begin to transform lands into healthy and productive farming spaces:

> One of the most recent answers to soil restoration seems to be in the proper application of the very highly potent hormone type chemical. Without the airplane and these new chemicals it would take us over 200 years to solve this problem but now it appears possible and logical to settle it in a period of five years...We must recognize the great amount of damage done annually by grasshopper infestation, which requires fast and effective control. The airplane, by the distribution of

> poison bran spread in their paths, can stop them in their tracks in a matter of hours. Any other disease-carrying insects can be eliminated through the spraying by airplane of selective chemicals which we now have.[7]

Thomas' first step for a national Ag plane program included an environmental-impact study of the non-productive lands in Oklahoma. He worked with the Red Plains Conservation Experiment Station to investigate the expanding aerial spraying industry in the Great Plains as well as the nation to study the noxious invasion of brush and other types of injurious pests and determine the variety of technological and environmental variables that adversely affected pilot performance and safety. Thomas' main goal: build an official aerial spray plane that can rapidly adapt to region, pests, and production quotas. Restoring the land to make it profitable again, he argued, could be achieved through a standardized spray aircraft that carefully managed the grasslands.

His case study focused on the Red Plains region, which included central Oklahoma, parts of Kansas, and Texas. The experiment station's preliminary report stressed the possibility of production and preservation of the grasslands could be achieved through a uniform and precise chemical application by air.[8] Removing invasive species of brush such as post oak-black jack, mesquite, and persimmon could open new areas for economic crops and pasture lands while at the same time re-establish a pasture cover of grasses that reduced soil erosion. According to the study, "some of this brush is located on shallow, eroded soil. This will necessitate careful management practices for the re-establishment of such land to a pasture cover of grass. Such a program will include brush control, erosion control, re-seeding with grasses and legumes, fertilization and pasture management. The program of sound land use can be greatly advanced by the development of a procedure of aerial treatment."[9] However, Thomas repeated the extension report's central warning about toxicity. Chemical land reclamation, the report said, had to come through accurate aerial treatment. Reckless flying or failing to keep chemical swaths to designated areas hurt fields for future generations. Through "proper technique and further development of 'know-how', a program of this nature will lead to a profitable, productive agriculture and the employment of millions of people on this vast area of useless land. And it will also control erosion and save the soil for generations to come."[10] Thomas' initial attempts to orchestrate an aerial spraying campaign for the grasslands also tried to address the growing dissatisfaction among farmers, agriculturalists, and applicators that current Ag plane technologies needed to adapt to the chemical and aerial dangers of applying pesticides low and slow.

An increasing amount of letters from farmers and aerial applicators suggested to Thomas that a flight training program and an "official" aircraft be developed similar to some of the schools and planes in the region. The regional diversity of the Great Plains and the spraying advancements by pilots such as Don Pratt and Roy Mahon in Kansas as well as the growing discussions at regional meetings such as the NCWCC all provided good evidence for standardization, but the more feedback he could receive from pilots around the country the better. To get a more accurate picture than the letters of praise or complaints from his Oklahoma constituents, Thomas issued an official congressional survey to gauge the current usefulness of aircraft in agriculture throughout the region and the country.

The response was overwhelmingly positive. Most identified pilot safety, chemical hazards, and technological and economic efficiency as the main issues. This provided Thomas the evidence he needed in September 1949 to draft a senate resolution organizing a federal-state-university program to build a "special airplane for agricultural purposes."[11] The Department of Agriculture, Civil Aeronautics Administration, and the Personal Aircraft Research Center at Texas A&M College each had a role in constructing an official aerial spraying aircraft that could address the variety of crops, pests, and agricultural landscapes across the country. Such an Ag plane was also much safer and more reliable than the current group applying pesticides over the Great Plains, argued Thomas, reducing risks to pilots and the public was central to this national program.[12]

In September 1949, E. M. Sturhahn, the Acting Administrator of Civil Aeronautics, wrote Budget Officer of the Department of Commerce F. R. Cawley to propose that the joint program that included regional representatives, universities, state officials, as well as federal interests. Based on Thomas' resolution and the numerous responses from farmers and pilots in the region and the nation, Sturhahn suggested to Cawley that a "general dissatisfaction with present aircraft dusting, spraying, seeding and fertilizing equipment." The Department of Agriculture, the National Flying Farmers Association, and other groups had made it clear to him that an airplane is needed that is "specifically designed for agricultural purposes."[13]

An official Ag plane is necessary, he said, because the current equipment consists largely of "converted military trainers, converted personal aircraft or obsolete bi-planes. None of these types have been designed for agricultural use and as a consequence their flight characteristics are not satisfactory for this purpose." Cawley was expressing the long-standing calls for standardization and safety that applicators in Kansas and other states associate with the NCWCC that began in the immediate postwar era. Approximately ten years had gone by with dramatic successes in chemical agriculture, but the hazards of pesticides to pilots, the public, and land required constantly adapting planes for accuracy and precision.

If an aircraft existed that could control problems of drift, chemical corrosion, dispersal rates with extensive recalibration, argued Cawley, farmers would be more inclined to hire applicators; pilots would be safer in the skies, and chemical hazards reduced. Both public and private interests, he held, failed to meet these "needs." The aircraft manufacturing industry "has failed to produce a plane that is capable of meeting the particular agricultural needs, and there are no indications that they ware willing to undertake such a project."[14] Both groups, however, created technologies and developed methods that addressed some of the consequences of chemical agriculture that could benefit the nation at-large. As Cawley concluded, "I should like to stress that the work involved is primarily the pooling of various ideas as to the design and operation of aircraft, for a special purpose in which the government is one of the primary interested parties. It is believed that such an aircraft will be of material benefit of the agricultural interests of the nation."[15]

A new spray plane design emerged that would link the regional knowledge of weed scientists and aerial applicators with the oversight and funding of the federal government. The chemical-technical advancements considered throughout its construction related to the hazards, practices, and standards experienced in grassland agriculture. The "first official spray plane," called the Ag-1, was built to reduce risk and increase operational efficiency. It embodied, at least for some, an important axiom of grassland application—that any agricultural airplane, at its core, had to work according to the region, crop, pest, and chemical being applied. Standardization worked because it considered variability.

In 1950, a diverse group of federal officials, agriculturalists, aeronautical engineers, and selected pilots arrived to Texas A&M's Personal Aircraft Center ready to build a farm plane for the nation. This new "flying tractor" prototype, reported *Aviation Week* in July 1951 represented the first "plane ever designated and built exclusively for super safe and efficient crop control flying." The Ag-1's main purpose was pilot safety, chemical efficiency, and adaptability.[16] According to lead engineer, Fred E. Weick, the Ag-1 needed a design that could address each of these factors related to performance. For him, plane design had to reflect the health of the pilot as well as the health of the fields. Drift dangers were not the only hazard—sprayers were risking their lives. As he recalled in his autobiography: "some of the requirements [for the Ag-1] were obvious from the start. With the pilot flying back and forth low over the crop and needing to clear trees, electrical wires, and other obstacles at the end of most runs, the field of view from the cockpit, both forward and downward, had to be excellent. Between swath runs, the pilot would want to turn back in the shortest possible time, and he would need to be able to see clearly where he was going." [17] Under Weick's direction, pilot performance in the dispersal of agricultural chemicals had to include a design that significantly protected the operator.

Uniformity in flying, handling, loading, maintenance, and repair was also necessary to keep Ag pilots safe, chemical dispersals accurate, and landscapes healthy. Innovations as simple as a guide-wire from the plane's vertical tail to the cockpit and sharpened landing-gear legs cut adapted to the expanding electrical grids in the Great

Plains and elsewhere by either cutting through them on contact or sliding a hot wire over the plane, keeping the plane in tact and the pilot safe from possible electrocution.[18] Other technical changes included easily repairable parts and upkeep procedures that allowed pilots to fix their planes in the field to continue to finish the job.

Weick also recommended that the Ag-1 add a protective shoulder harness that could keep the pilot from colliding with the instrument panel or the cockpit in the event of a crash. A seemingly simple improvement that combined a naval harness with an ordinary seatbelt was actually a novel idea in aerial application, according to Weick, because most aviators felt that low-speeds meant safe escapes. Working against an attitude of pilot invulnerability, he understood that this modification could be implemented as an extension of the Ag-1's "safe design."[19] Although Weick contributed to two additional prototype models (the Ag-2 and Ag-3) throughout the early 1950s that guided aviation companies to build an industrial line of super spray planes in the 1960s and 1970s (Piper's Pawnee remained closest to the original design), his most important set of recommendations involved the study of aerial spraying's chemical hazards.

Protective equipment was needed in the cockpit, of course, but pilots, workers, and flagmen associated with the aircraft also had to be sure of the plane's dispersal accuracy. Weick's warning to the participants at the Fifth Annual Texas Agricultural Aviation Conference in 1956 was clear: pesticides were toxic and accuracy and performance of the Ag-1 had to include precautions against these poisons. "Here again facts speak for themselves. They indicate that use of shoulder harness, crash helmets and proper protective equipment for the application of poisonous chemicals is certainly worthwhile." But effective performance meant handling pesticides safely, following labels, and understanding how the poisons worked in the larger environment. “Almost all the compounds that destroy weeds and insects can be harmful to human beings,” Weick noted, citing a Monsanto pamphlet on safety for pilots, “some such as organic phosphates are extremely poisonous. But there is a right way, a safe way to handle them. Learn and observe these fundamental precautions…All insecticides and herbicides are considered toxic. You should avoid breathing them and avoid contact with skin, hands, eyes.”[20]

Additionally, Weick held that special precautions needed to be taken with new synthetics appearing in the agricultural chemical market. Spraying parathion, systox, or similarly potent chemicals required increased safety. Pilots, he recommended, should not stay in the plane during the chemical loading process, wear specialized masks, and, if possible, use some other means than flagmen to outline swath dispersal lines. Weick also stressed that special care should be taken to clean the aircraft after every use and dispose of any chemical excess with the utmost care: “make sure that the waste is not blown or spilled in such a way that it will endanger humans or livestock.”[21]

A third reform that the Ag prototype series promoted involved field flaggers. Weick suggested at the Texas conference that each worker in the field needed to “become familiar with all precautionary measures and see that they are followed carefully.” While a good rule for pilots and flaggers overall, Weick supported excessive precautions for high-potency sprays. “In every case,” he demanded, “when using flagmen, special care should be taken to prevent them from coming in contact with the spray, and to make sure that they do not walk through sprayed plants.” Chemicals like parathion could easily absorb into a flagger’s skin, entering the bloodstream to damage organs or harm nervous systems. To guard against this workers needed to familiarize themselves with labels, discuss the dangers with pilots, and understand the instructions for dealing with poisonings—"they should carry a small supply of atropine at all times, and in case of suspected poisoning administer a dose and then rush…to the most available doctor or hospital."[22]

In addition to his assessment of the health and safety of the pilot, flaggers, and the plane itself, Weick restated a medical inquiry done by Frank Princi of the University of Cincinnati in 1952. For both men, applicators needed common sense more than any other ability when dealing with pesticides, especially organic insecticides. Princi had published it four years earlier at the Second Annual Texas Agricultural Aviation Conference, but Weick felt the need to reiterate his findings to the current crowd. "One knows," Weick read, "that none of these materials should be handled continuously with bare hands. They should never be inhaled in large quantities, and finally they should never be allowed to remain in contact with the body over any appreciable length of time." However, Princi's next suggestion was even more fundamental to both the audience and the region: "Despite the fact that today we do not know the quantity necessary to produce acute intoxication in humans, we do know the quantities which will not produce intoxication and the person who employs these materials never absorbs in ordinary practice, a sufficiently large quantity as to produce injury."[23] Similar to the findings of aerial applicators and weed scientists further north in the central plains, Princi and Weick described a method inherent in the farmland standard that identified procedure and region as important variables in determining toxicity. Unseen chemical dangers could be reduced if standard mixing and application procedures were followed. The report assured pilots that their worries about toxic accumulation from constant use and the residual presence of chemicals were legitimate but had not been shown in laboratory tests: "most persons are concerned not because of any obvious reactions to insecticides but by the fear that they may be accumulating the substance within their body unknowingly and that some day a sudden acute illness will develop. This has not been shown to be the case in animal experimentation."[24]

Most applicators in other parts of the Great Plains supported the Ag prototypes and the other reforms expressed by Weick and the Texas Agricultural Aviation Conferences. Many felt the Ag-1 series reinforced principles of standardization and safety stressed by other pilots in the region. Early interactions between chemicals, farmers, sprayers, and pests in the immediate postwar era had created a litany of private spray planes and applicators that followed the precepts of pesticides. These varieties helped create the chemical-agricultural landscape that could produce with new vigor; it also came with new problems and hazards. Standardization and attention to chemical selectivity and how the toxic principles of DDT, 2,4-D and other pesticides related to pests, fields, livestock, and communities helped produce this new Ag plane version. However, these same elements that produced it also undercut its changes with some regional pilots.

Certainly, Weick's designs and principles convinced sprayers/agriculturalists such as R. E. Larson of the University of Missouri to urge his fellow pilots at the 1952 NCWCC conference in Winnipeg to incorporate the Ag program's findings, but not necessarily purchase a new plane. Costs, noted Larson, proved too high for pilots to purchase a similar design by Piper called the "Pawnee." Because all pilots and aircraft companies had access to the program's findings, technical additions, and overall performance reviews—many sprayers in the region submitted surveys to the Ag-1 group and test flew the prototypes—a better solution, perhaps, was to keep their planes and make the additions.

Larson did endorse the growing critiques of parathion and similar types of pesticides with an increased potency. Anticipating the growing challenges of highly toxic compounds being manufactured and used on the grasslands, Larson warned that pilots should look at the Texas findings and seriously consider adapting their aircraft and application procedures to reflect the dangers. He wrote, "Another safety problem which is being heard of more and more is that concerning the use of parathion. One company has attempted to overcome the hazards of the use of parathion by moving to the outside of the fuselage all parts of the spraying equipment which carry the chemical under pressure."[25] This method, Larson insisted, gave pilots additional protection against the poison. Additionally, some pilots, he said, moved their spray tanks under the plane or constructed a "belly tank," for especially toxic chemicals. He warned however, that this so-called "safety improvement" could endanger as much as it protected. This modification, according to Larson, was really only suitable for "those planes which apply parathion exclusively," because most operators feel "that the external tank produces too much drag such that in some cases the cure would be more hazardous than the possibility of the parathion poisoning."[26]

Larson also contested the idea that federal funding and the new designs that emerged from the Ag-1 prototypes adequately addressed the region's agricultural and environmental variability. It seemed to him like the tests overshot the plane's technological abilities as well. "There are limits," cautioned Larson, "to such changes, those limits being controlled by the flying characteristics of the original design." As pilots throughout the region understood that the rule to standardization for the Great Plains was variability, anticipating and adapting to unruly conditions, crop and pest diversity informed chemical selectivity—the same was true for the aircraft itself. The problem with the Ag-1 prototypes, for Larson, came with an assumption that adaptations on such a streamlined sprayer could be accomplished by anyone, even novice pilots that were new to the industry. He listed examples in which an aircraft "has been indiscriminately changed by people who had no knowledge of the aerodynamics concerned with the design of safe aircraft. I believe that many projects would do well to get qualified technicians to provide safer design and also to save money over their present cut and dry methods."[27] An even more important danger addressed in the Ag-1 program was flagging. The ground crew played a crucial role in the accuracy of the Ag pilot, but they also encountered the greatest risk of economic and chemical hazard. Larson believed that Weick and the national program was a promising start, but much more needed to be done concerning the health and well-being of flaggers, farmers, and others participating in the crude guidance system.[28]

The regional contribution of the Ag prototypes would be the first of many examples of how the evolution of aerial application in Great Plains contributed to the nationalization of agricultural aviation. The standards and relationships related to the pesticides—selectivity, adaptation, and toxicity—were identified in a host of state and federal spraying manuals and handbooks throughout the 1950s and 1960s. As USDA officials attended NCWCC meetings and aerial spray conferences with the regional applicators, the techniques, attitudes, and practices of spraying the grassland way would inform how federal officials recommended all pilots to fly. Manuals such as "How to Spray the Airplane Way," first published in 1952 and reprinted in the 1960s, expanded on these regional developments.[29]

An equally important consequence of this relationship was the growth of spraying organizations in the region and across the nation. As Weick and his group flew around the country, allowing Ag pilots from other agricultural areas to test the planes, sprayers and dusters talked to one another. Pilots from Kansas, Iowa, Oklahoma, Texas, Nebraska, and Minnesota all contributed to a network of groups that met annually to discuss the various technological developments. Many applicators participated in fly-ins to demonstrate their expertise for farmers and to answer questions about chemical mixtures, dispersal rates, and laws. In 1958, for example, Kansas Ag pilots formed an association to address the developments of aerial spraying, its problems, and state regulations. The Kansas Aerial Applicators Association (now the Kansas Agricultural Aviation Association) originally consisted of a group of 22 spray operators, who endorsed many of the same principles that Don Pratt emphasized nearly a decade earlier.

The association provided local pilots the ability to organize against weed infestations, deal with hazard reports, and assist each other in understanding the latest label requirements and regulations. Similar organizations appeared in Oklahoma, Iowa, Nebraska, and Texas and they worked together to found a national chapter in 1966 to address noxious weed infestations, insect attacks, study new chemicals, and review state and federal laws.[30] The tendencies of pesticides that had connected and remade farmers, applicators, and weed scientists in the Great Plains helped create a regional and interstate sprayer network that would have a voice in the tumultuous political climate ahead.

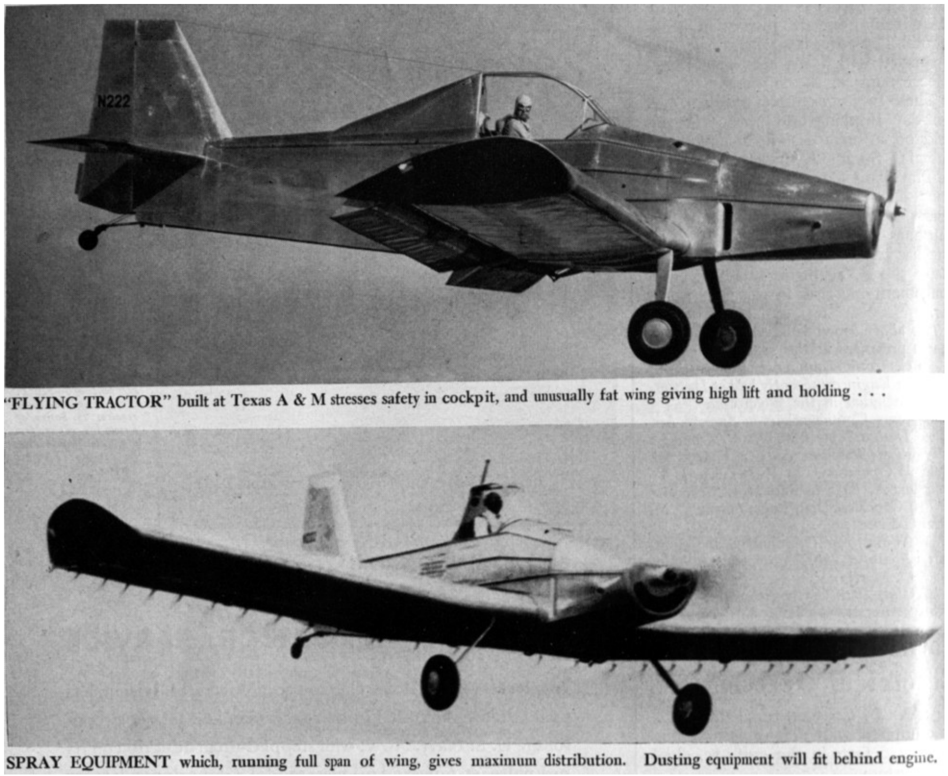


Figure 18. Test flight photographs of the Ag-1. Reprinted with permission from *Aviation Week*, July 16, 1951, (42).

New Politics and Laws in the *Silent Spring* Era

The warnings discussed by Weick in the 1952 NCWCC meeting over newer poisons such as parathion illustrated a practical awareness of pesticide dangers that would inform a vision of agricultural health during the 1940s and 1950s. The tendencies of farm poisons in the region and their creation of ensembles of producers, application, and pests contributed to a patchwork of environmental laws that predated Rachel Carson's critiques in the 1960s and the EPA's oversight in the 1970s.

Many of these controls in states such as Kansas, Iowa, and others followed the precepts of the 1947 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which established, according to environmental law historian Karl Brooks, an important environmental law principle that informed future pesticide legislation: "uniform national standards should regulate manufacture and sale of chemicals that could sicken people and pollute natural systems."[31] The central tenant of this law was to safeguard "human health and ecological integrity." Manufacturers were forced to register their "economic poisons" with the USDA, provide adequate mixture requirements, and direct users, in clear language, that the contents of their containers "were toxic to humans and a wide variety of life forms."[32]

Additional sections of the law afforded the USDA enforcement powers in label, mixtures, and sales as well as revisions in registrations. The federal office had the ability to cancel a chemical in "order to protect the public," making any additional sales of the compound illegal. Furthermore, FIFRA mandated a five-year production span for manufacturers, which forced them to supply farmers with updated information on "the product's purposes, composition, and toxicity." Section 6, as Brooks notes, was crucial in this regard because it authorized the USDA to "revise its registration thresholds as science and practice warranted." Manufacturers had to provide evidence "to determine [if] economic poisons, and quantities of substance contained in [them],…are highly toxic to man."[33] Although amended multiple times, through the Delaney Clause and Miller Amendments, this and gave regulatory power to the EPA in an attempt to prevent environmental toxicity, FIFRA did not go far enough to prevent environmental pollution.[34] This was especially true when it came to custom application, specifically aerial spraying. While basic language existed in the law about application safety, none specifically addressed spraying the airplane way. This left the issue of contracts, performance, and hazard negotiation up to the states. As discussed in earlier chapters, many of the early precautionary efforts were enacted by pilots and weed scientists but states in the Great Plains were at least exploring, if not implementing new regulations for aerial spraying. Part of North Dakota's 1949 weed control program, for example, included collaboration between the state's civil aeronautics board, its airplane operators association, and the extension service to improve both chemical selectivity and applicator performance.[35]

As R. B. Widdifield reported to the NCWCC 1949 meeting, "a plan was worked out with and agreed to by [these groups] wherein before a low flying permit would be issued by the Civil Aeronautics Board to any airplane operator that copies of our extension recommendations for both selective weed control with chemicals and recommendations for the use of fungicide applications would be provided to operators and that before issuing a low flying permit all such operators would certify they were familiar with our Extension recommendations."[36] Applicators also agreed to implement a uniform reporting process to the CAB which included daily documentation of chemical types, application rates, and crop conditions. Any hazards, problems with drift, or mistakes had to be included. Finally, if chemical damage claims were left unsettled, pilots would be unable to acquire their low-flying permits for that year.[37]

These early attempts to regulate the manufacturing, sale, and application of pesticides established a legal framework that attempted to protect agricultural health both in economic as well as environmental terms. By 1962, however, this version health and its farmland toxicity standard would be contested by Rachel Carson in *Silent Spring*, which was, in the words of historian Robert Gottleib, “an epochal event in the history of environmentalism.”[38]

The main tenants of this social movement saw pesticides and the environment in a holistic way, asserting that farm chemicals contaminated more than they protected: “along with the possibility of the extinction of mankind by nuclear war, the central problem of our age has become the contamination of man’s total environment with such substances of incredible potential for harm—substances that accumulate in the tissues of plants and animals and even penetrate the germ cells to shatter or alter the very material of heredity upon which the shape of the future depends.” Carson described a future that contested the vision of health and economic production of pesticides, highlighting instead the disastrous biological consequences of using poisons with “little or no advance investigation of their effects on soil, water, wildlife, and man himself.”[39]

Carson’s portrayal of health, according to historian Linda Nash, “owed much to her strong sense of corporeal connection to the landscape, and her ecological perspective made her far more willing than most contemporary physicians to postulate the intermixing of bodies and environments.” *Silent Spring* stressed that pesticides, specifically DDT, had unknown and long-term effects on humans and nonhumans alike—that there was “a very limited awareness of the nature of the threat. This is an era of specialists, each of whom sees his own problem and is unaware of it or intolerant of the larger frame into which it fits.”[40]

Carson’s challenge of agricultural modernity and its faith in science also asserted that industry influenced policy. “This is also an era dominated by industry, in which the right to make a dollar at whatever cost is seldom challenged.” These forces combined, she argued, to mitigate the risks to the public's safety as well as the larger environment's health. "When the public protests," Carson held, "confronted with some obvious evidence of damaging results of pesticide application, it is fed little tranquilizing pills of half truth. We urgently need an end to these false assurances, to the sugar coating of unpalatable facts."[41] Indeed, if the public had to assume the risks, she wrote, then they must have the power to "decide whether it wishes to continue on the present road, and it can do so only when in full possession of the facts…the obligation to endure gives us the right to know."[42]

Passages such as this sparked a socio-political fervor from agriculturalists, manufacturers, applicators, farmers, and the public throughout the country. Historian Thomas Dunlap suggests that throughout the 1960s, DDT became the chemical "that people loved to hate."[43] Even more central, however, was Carson's insistence on local experiences and health concerns as equal to that of convoluted and perhaps suspect toxicology findings by chemists in laboratories. Chemical toxicity could be felt and experienced, not just studied, which meant environmental health could be known, not just understood. As historian Linda Nash put it, "Moreover, controlled laboratory spaces and inbred rats could never account for the complexity of actual bodies and actual environments…*Silent Spring* spread the activity of knowing health widely, recruiting the experiences of wildlife experts and housewives, the materials of the toxicology laboratory and the clinical physician, the natural histories of grebes in a northern California lake, and the experience of farm workers in the Central Valley."[44]

Throughout the aerial spraying community in the Great Plains, a similar retort emerged, but from a vision of agricultural health. Many pilots feared (and national organizations such as the National Agricultural Chemicals would stoke these fears) that overregulation of pesticides or aerial application procedures would be one of the consequences of the post-Carson era, but they were not completely averse to regulating their use. Pilots' longstanding efforts to curb overuse, recklessness, and chemical drift hazards aligned in a practical sense with her insistence of local conditions, experiences, and human–nonhuman interactions to calculate the dangers.

Put another way, the political debates created a conflict between the agricultural health ethos in the Great Plains and an environmental health ethos that was built upon ecologist Aldo Leopold's assertion of an ecological conscience—that a "thing is right only when it tends to preserve the integrity, stability, and beauty of the community, and the community includes the soil, waters, fauna, and flora, as well as people"—and expanded by Rachel Carson in *Silent Spring*.[45] However, the workings of pesticides in the grasslands also generated standards, techniques, and attitudes that calculated chemical risk, maintained an awareness of pesticides' dangers, and in practical ways, agreed with Carson's critique that it was dangerous to put "poisons and biologically potent chemicals indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm."[46] For many of them, farm poisons were as unruly as their applicators. Thus, following procedures, labels, designing new spray technologies, and matching chemicals and application procedures to pests and environmental conditions allowed them to guard against poisonings while also protecting the agricultural sanctity of the region.

"Indiscriminately From the Skies" and Chemical Bootlegging on the Ground

One place to view these interactions between politics, policies, and problem sprayers is in Kansas. As early as 1945, Kansas newspapers such as *Capper's Weekly* were warning that the dawning of the chemical age for agriculture had as many dangers as promises.[47] One of the hazardous tendencies of pesticides came from criminal applicators. Agricultural health, in this way, related to guarding against rogue sprayers or chemical bootleggers in the same way it encouraged technological adaptation or standardization. Indiscriminate sprays from the skies or faulty chemical mixtures in the fields damaged crops, contaminated the soil, poisoned the reputations of other Ag pilots, and often harmed residents.

Multiple damage and injury reports to the Board of Agriculture reveal that unethical applicators charged cheaper rates than the more legitimate outfits by selling faulty mixes and sprayed fields with little concern to air currents, field boundaries, or county lines. Renegade operators frequently failed to pay attention to wind direction, geography, or crop specificity.[48] These elements that challenged licensed pilots could translate to deadly consequences when "amateurs," as Donald Pratt called them in a 1949 interview with the *Topeka Capital Journal*, refused to follow certification requirements or sprayed the wrong fields.[49]

These "itinerant, irresponsible, and illiterate pilots who got a thrill out of illegal buzz jobs" also exploited the growing relationship that most farmers had with agricultural chemicals to continue their haphazard activities.[50] They knew that landowners, while victims of these poisonings, would most likely stay silent or send nondescript damage claims to the Board of Agriculture because of the equally great threat to their crops' health. Since many farmers, officials, and aerial applicators tended to view the dangers of chemical and natural toxicity together, they were reluctant to increase restrictions on pesticides or herbicides. Protecting their fields from weedy contaminants meant acknowledging the dangers of chemicals and toxic drift but shifting the blame to irresponsible applicators. Even alleged Ag pilot intimidation or excessive spray mishaps that prompted more direct confrontations did not dissuade landowners from using pesticides, but rather they embraced tighter restrictions on applicators.

However, rogue sprayers were only part of the problem. Local formulators and dealers also took advantage of farmers' chemical dependence by carving out a niche market that included as many underhanded dealings as legitimate ones. Examples of chemical bootlegging can be found early in the postwar era with local dealers practicing a process called "incorporating" in which merchants took two or three different pesticides and mixed them together in an unmarked container and then repackaged the adulterated poison as a different chemical.[51] This tactic allowed formulators to charge farmers or aerial applicators a premium price for chemicals anything but safe or effective. Since the landowner and Ag pilot really had no way of knowing what was inside of the container before its use, the deception was only discovered after the job when farmers' crops either perished from excessive chemical poisoning or continued infestation because the concoction was too weak. This type of bootlegging operation often escaped detection because landowners tended to blame Ag pilots first for spraying mistakes. Rogue dealers could also claim they simply miscalculated their mixtures as many pesticide manufacturers, by the 1960s, were recommending chemical combinations to deal with pest resistance and tolerance (see Table 4). However, mixing adulterated compounds in “unofficial toxicology labs” hidden in backrooms of hardware stores or in remote warehouses assisted in their anonymity.[52]

Another bootlegging scheme was mislabeling. This method was more prolific since formulators often recycled empty chemical drums with new products. In an effort to “create” the kinds of poisons farmers and Ag pilots wanted, dealers saved labels from other previous containers and reattached them to new barrels with entirely different chemicals. This kind of marketing deception certainly played a crucial role in the incorporating process, but bootleggers just as often simply changed the labels without removing the contents. So if farmers or applicators ordered an herbicide, they might actually receive an insecticide or a combination of both.[53]

State regulatory action through the Kansas Agricultural Chemical Act (1947) attempted to control these violators by creating a legal framework that controlled the chemical mixture amounts, labeling requirements, public health, and environmental safety. Following many of the tenants of FIFRA, the KACA tried to address the labeling and sale of pesticides, but it did not go far enough to regulate the users. This was especially true regarding aerial application.[54]

In a response to the concerns of both farmers and Ag pilots, the state legislature passed the Kansas Aerial Spraying Law in 1951 to establish an additional set of regulations that enforced professionalism and chemical knowledge in the skies while putting a framework of legal protections for landowners on the ground. Under the new law, applicators had to register their plane with the state, and accept a bond that covered at minimum $2000 for their first plane and $1000 for each additional plane. Ag pilots also had to keep detailed records of every job including a description of location, pest, chemical dosage applied, and the landowner who hired them for aerial treatment. Applicators found guilty of damages or malpractice faced fines or jail time.[55]

Various revisions to the Kansas chemical laws throughout the 1960s and 1970s reinforced the idea that field health and contamination came from a variety of threats, including wrong chemical dosages, drift, and weedy pests, but it failed to touch on the long-term pollution of soil, water, and public health hazards. Landowners and pilots expressed a general willingness for better legal controls over how agricultural chemicals were developed, sold, and applied. Most farmers and Ag pilots agreed that violators needed monetary and criminal consequences to address their recklessness, but their concerns were as much about the extent of state and federal management as with the potential harm of drift or chemical bootlegging.

New calls for restrictions and a rethinking about the standards by which agricultural chemicals were used from environmentalists and the EPA in the 1970s challenged how toxicity was viewed on the farm and in the air. While farmers, Ag pilots, and weed supervisors had developed a standard that they believed included a precautionary vision of pubic and environmental health as it related to protecting crops and profits through education, accuracy, and regulation, it was one increasingly at odds with the new ecological visions of safety and health that environmentalism asserted and the EPA enforced. The legislation also did not live up to agricultural health standards set in the region.[56]

For their part, Ag pilots in Kansas remained dedicated to the principles of the farmland toxicity standard but adapted parts of it to the new social and policy realities of the era. Applicators continued to learn the new restrictions implemented by the EPA and remained dedicated to accuracy in dosages and dispersals. They also constantly sought new techniques to address the hazards of drift and chemical contamination. As KAAA President Fred Clark explained in a 1968 interview with the *Kansas Farmer*, new methods such as Ultra Low Volume application (ULV) allowed pilots the ability to apply "concentrated but low-toxicity chemicals at volumes of only a few ounces per acre. This eliminates the need of diluting the chemical with water or other additives."[57]

Changes in the Kansas chemical laws also highlighted the merging of these longer-term concerns of environmentalism and the EPA with the farmland toxicity standard. The Aerial Spray Law, for instance, was amended in 1965 to the "Kansas Chemical Spray Law" to include ground equipment or any other "owner or operator of dispersing equipment." Farmers also had to apply for a spraying permit and register with the state. Furthermore, new legislation demanded applicators of all types participate in chemical-mixture training sessions, take flying exams, keep their permits up to date, and agree to impromptu inspections, allowing officials to oversee company activities at any time.[58]

Figure 19. This photo was included in the Board of Agriculture's Pesticide investigation files, which provided an illustration for agents of illegal mixing (c. 1950s). Courtesy of the Kansas State Historical Society.

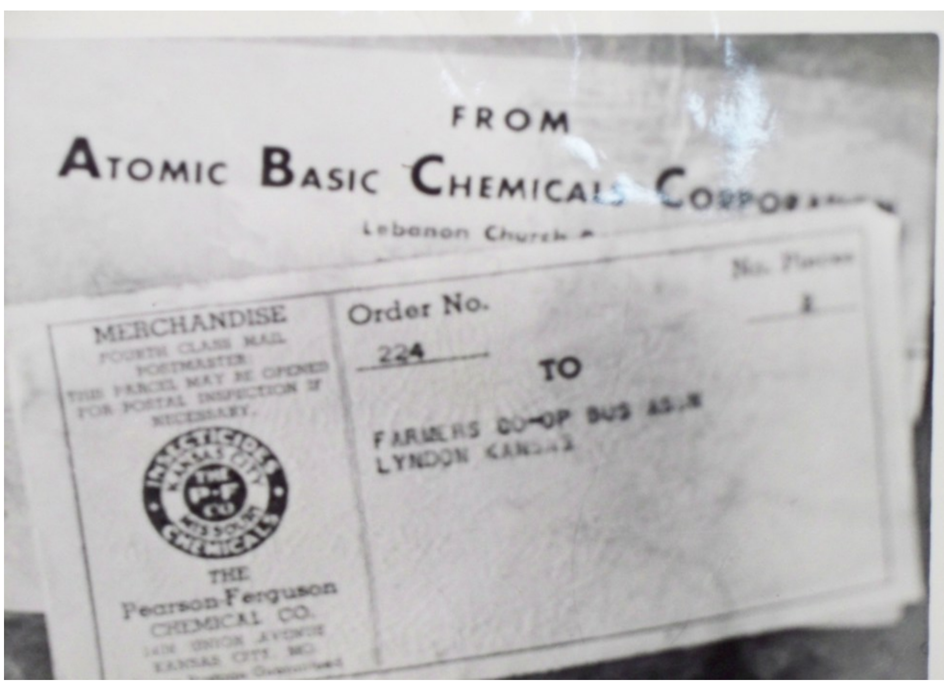


Figure 20. This photograph is an example of mislabeling. Board of Agriculture agents caught the dealer before he could remove the old label, c. 1950s. Courtesy of the Kansas State Historical Society.

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The post-Carson political environment, or what an Iowa State extension expert referred to as the "After Carson" or "AC" era, saw numerous legal and instructional reforms in the Great Plains that reflected the current political debates around DDT and other farm poisons and their pending regulations.[59] States like Kansas, Iowa, and Nebraska passed chemical legislation and instituted new studies on aerial application in an attempt to reconcile the economic benefits of pesticides with the newly discussed environmental dangers. Moreover, pesticide policies in the Great Plains tried to reform the agricultural health ethos to fit into the new regulatory framework encouraged by the politics of environmental health. However, the tendencies that had been remaking the region into a chemical-agricultural landscape continued to inform how farmers, Ag pilots, and weed scientists responded.

For example, both versions of health shaped Iowa's pesticide law.[60] The Iowa Pesticide Act of 1964 stipulated that any new farm chemicals be registered with the secretary of agriculture and tested by official state labs to determine residue levels. Furthermore, all custom applicators had to register with the state and acquire official license. Although these new efforts represented attempts to address environmental health concerns, they were relatively lenient on individual farmers because, writes historian Joe Anderson, the act "did not require any training or regulation for farmers who applied their own chemicals … it was recognition that some degree of oversight of farm chemicals was necessary, if for no other reason than to quiet public concerns about the impact of pesticide use."[61] Custom sprayers were under new restrictions, but for most farmers "it was business as usual since they were exempt from special training."[62]

The conflicting visions of health, however, played out in landowners' mixed reactions toward the new rules in 1971. *Wallace's Farmer* surveyed farmers about pesticides a year after the EPA's inception about applicator oversight. "Many Iowa farm people [38 percent] foresee problems" the piece read, "if the application of persistent pesticides is limited to licensed operators. But about the same percentage [38 percent] think this might be a good idea."[63] The group with more college education tended to support licensing plan. As a young farmer from Davis County asserted, "these pesticides are far more dangerous than people think. I'd agree we are badly in need of licensed applicators." Another, older farmer feared stronger regulations of farm chemicals and applicators: "I'm afraid the bugs and weeds would take over. How do you get licensed applicators out to do the job when it ought to be done." As Anderson concludes in his study, many farmers "recognized that there were hazards associated with chemical use, but government regulation was a divisive issue."[64]

In Kansas, many farmers and agriculturalists expressed a similar ambivalence about regulation but recognized the threats to both farm health and environmental health. As Kansas State University entomologist Clyde Zimmerman noted in *Kansas Farmer*, many new pests required watching in the spring of 1970; chemical application was best at controlling them. Zimmerman made a point to address the changing government regulations on farm poisons, specifically DDT, and the fears of pending infestations. The government's ban on DDT, he noted, "made little difference to Kansas farmers. With the exception of spot treatment for Dutch Elm disease control, and minor use against corn borers, DDT has not been recommended in any significant amounts by K-State for some time."[65]

Ongoing spraying mishaps, however, did cause Kansans to demand reforms. Rural residents pleaded with state and federal officials to restrict aerial spraying specifically, suggesting that licenses, lawsuits, and regulators would never curb the hazards of pesticides. Writing to Senator Robert Dole in the summer of 1969, the Gandys explained their 23 acres in Woodson County had been illegally sprayed by an aerial applicator that was hired by neighboring landowners: "some of the farmers had their pastures sprayed for weeds and other things the last week in May. Since then most of our fruit tree[s] have died or are dying, the rest of the garden has been heavily [sic] damaged, even the shade trees have been injured...the fumes [were] so bad, we had to go inside for our own protection."[66] They concluded pleading with Senator Dole to support increased oversight of sprayers—"Is there no law to protect us and our property? If not then we might as well give up."[67]

The Gandys were not the only residents to recognize the health hazards of aerial application. Ralph McGinty, a farmer in northeastern Kansas, awoke in June of 1972 to a similar chemical mishap. His crops had been illegally sprayed by a rogue pilot. According to his report to the state's Board of Agriculture, he had heard rumors of a spray pilot terrorizing farming communities nearby but had hoped these "errors" were simple mistakes. But now that his fields were contaminated, he believed his neighbors' stories:

> My fields have turned orange and yellow, my tomatoes are wilted, and my fruit trees are dead and dying…all by the same pilot who has caused destruction in several other nearby locations and is being sued by landowners that can afford to hire lawyers. In spite of such a record this man is licensed to spray. Can a lawsuit replace my crops, livelihood, or even the native trees that used to shade our house? What in God's name will shade our house…a lawsuit? How long must landowners sue? How long will we tolerate destruction to drift with the wind? Must I start all over again only to have the state license this same pilot or some

> other idiot to spray me again. Let's stop it NOW…this year. If these people cannot be controlled, they must be stopped.[68]

In 1976, however, an even larger spraying accident eclipsed the McGinty Farm incident as a plague of army cutworms attacked wheat fields throughout central Kansas. Sumner, Cowley, Harper, and Sedgwick counties all viewed aerial applicators as the primary vanguard against pending infestations of their wheat crops. An armada of sprayers arrived in February to apply Endrin, a highly potent pesticide. However, chemical protection had poisonous costs, and residents experienced what some officials and witnesses would later call the "worst pesticide application disaster the nation has ever known."[69]

Millions of acres were excessively sprayed by pilots who failed to follow pesticide label instructions, fly at accurate altitudes, and turn off sprayers. State debates in 1976 had already been raging about the dangers of agricultural chemicals and their regulation for aerial application. This disaster that killed a multitude of fish, livestock, and poisoned lands and communities would ultimately spur a comprehensive review in Kansas of many chemicals used on the farm and how they were applied. The result placed an emphasis on expanding regulations on "safe" aerial application to prevent "outlaw" pilots rather than banning chemicals that had been so effective in controlling insects and weeds in the past. As William Greenwood, an administrator in the Kansas Department of Agriculture, put it, banning these chemicals "is not the thing to do. We need to ban irresponsible applicators."[70]

Ag pilots also responded to these regulatory changes. The increasing scrutiny that came from the *Silent Spring* era and the banning of DDT in 1970 caused pilots to worry about the growing amount of restrictions and revised label recommendations for other pesticides. In 1976, new label suggestions for 2,4-D by the EPA sparked a pilot write-in campaign to the Kansas Board of Agriculture. Most operators were concerned about how their businesses and reputations would be harmed by chemical reforms that were the result of the unethical practices of a few.

Sprayers such as Jim Floyd of Liberal, Kansas wrote the Kansas Board of Agriculture in 1976, insisting that for over seven years he had been in the aerial application business as a sprayer or participating as a pilot crewmember "in the spraying of over 900,000 acres of crops with numerous chemicals"—all with rates that were below five gallons an acre. And "experience has proven this method of application to be effective, safe, and economical."[71] Other pilots joined Floyd in worrying about the regulatory expansion they had witnessed with DDT. And they expressed concerns over that criminal formulators and applicators over the last decade would only provide more evidence for regulations that could severely damage their livelihoods as well as the agricultural health of the state.

Challenging new herbicidal label requirements that restricted the amount of 2,4-D allowed by air, pilots highlighted the ongoing regional tensions between officials, users, and pesticides. Many argued that achieving both goals of economic efficiency and agricultural health required chemical amounts that should be selected according to the specific weed, crop, and environmental conditions of the spraying area—not prearranged amounts determined by laboratories and politically driven precautionary standards.[72] Ag pilot Frank Bringham of Mede, Kansas noted, for example, that he had used "[2,4-D] in all formulations for in the range of one and one half to one and three-fourths million acres. The bulk of this was done using one gallon and in some instances even less. In those instances it was done on an elective basis, where the coverage would be better using one half gallon than any other gallonage [sic]."[73]

Bringham accentuated an important part of the farmland toxicity standard. Laboratory recommendations of toxicity articulated in labels often did not conform to these other conditions. In this case, to implement maximum and minimum standards for 2,4-D formulations in the spirit of chemical hazard and environmental health did not address the variety of conditions that pilots experienced in Kansas and the region. For Bringham, these types of label restrictions completely failed to account for the "field experience" they achieved over decades of application experience: "In the case of aerial application the volumes I speak of range from one half to seven gallons. This has been the practice from the start because at the start we had no guidelines and no one dictating the need for a wide swath high or low gallons, so it was pretty much by experiment. From that we have had good and bad experiences…So for the matter of the various 2,4-D formulas, in order to cover a satisfactory swath evenly, I know of no other way to do it than stay with the maximum of one gallon and manipulated pressures and nozzles."[74] Bringham insisted that the Ag pilots' herbicidal calculations came from years of adapting to potency, weed populations, and the region—"Again, if we are in dense foliage, we are forced, reluctantly, to use higher gallonage [sic]. In the open country, rangeland, pasture, and the like I would certainly recommend one gallon for good results over the higher volumes."[75]

Other pilots, such as Robert Murphy from Ulysses, Kansas wrote that low-volume spraying of 2,4-D and the adaptation of aerial application standards to pesticides and the terrain kept amounts low, mixtures diluted, and drift hazards down. Murphy noted that he had been in the application business for 10 years and sprayed on average 10,000 acres per year of various formulations of 2,4-D to wheat, milo, corn, and pasture:

> I normally apply 2,4-D with 1½ gallon water with no harmful effects and doing a superior job of coverage for good performance…Aerial application is the only method available to the farmer to apply 2,4-D to wheat and many cases to pasture due to rough terrain. Aerial application of 2,4-D has been a standard farming practice in this area since 1948 that I know of. With higher gallonage the application cost becomes prohibitive.[76]

Sprayer Walter G. Guth of "Sprayers Incorporated" in Atwood, Kansas joined Murphy's appraisal of historical spraying in his letter to the Kansas Board of Agriculture in the summer of 1976: "I started in the aerial application business in 1949 and I have sprayed 2, 4-D as well as other pesticides every year since that time. The amount of Wheat treated for weeds has varied from 5000 acres to 60,000 acres per year, [and] never have we applied over one gallon per acres total volume." Guth insisted that the regional variables kept these spraying amounts low and that "one gallon output has been standard practice since I started spraying, and results have proven that this amount is sufficient."[77] Other states such as Nebraska passed similar pesticide laws that required licensure requirements. The state also updated their extension spraying handbooks to reflect the new regulations and environmental specifications. The *Handbook of Nebraska Spraying*, for example, updated guidelines that provided pilots with a host of new spraying instructions, pesticide mixture ratios, and attempted to link pilot health with environmental contamination (see Table 4).

Toxicity of Herbicides

Material	Oral toxicity LD-50 Mg/Kg	Dermal toxicity LD-50 Mg/Kg	Hazard
Table salt	About the same as dalapon		For comparison
2,4-D	300-1,000 (rats, mice, guinea pigs and rabbits)		Low
MCPA	Low		Low
2,4,5-T	300-1,000 (rats, mice, guinea pigs and rabbits)		Low
Silvex (2,4,5-TP)	650 (rats)		Low
4-(2,4-DB)	Low		Low
2,3,6-TBA	700-1,500 (rats)		Low
Amiben	5,620 (rat)	3/60 (rat)	Low
Amitrole	15,000 (rat)		Low
Arsenites (Na/K)	70 (rat)	150 (rat)	High
Atrazine	3,080 (rat)		Low
CDAA (Randox)	700		Low
CDAA + TCBC (Randox T)	Relatively low		Low
Dalapon	6,600 (rat)		Low
Diquat	400-440 (rat)		Low
DNBP (Dinitro)	50 (rat)	200 (rat)	High
Endothal	35		Moderate
EPTC (Eptam)	1,630 (rat)		Low
IPC; CIPC	1,000-4,000 (rat)		Low
Monuron, Diuron	3,400 (rat)		Low
NPA (alanap)	8,200		Low
PCP (pentachlorophenol)	80-200 (rat)		Moderate
Simazine	5,000 (rat)		Low

Table 4. An example of an updated chart for Nebraska Sprayers. It surveys some of the most common herbicides and their toxicity. Reprinted from the *Handbook of Nebraska Spraying*. 1962.

These regional debates also continued to shape the nationalization of aerial application. The EPA's guide to aerial spraying, published in 1976, endorsed many of the technological adaptations and practices of spraying the grassland way. Pilot George F. Mitchell Jr from M & M Air Service of Texas and Dick Reade from Mid-Continent Aircraft Corporation of Missouri contributed to the guide along with representatives from the NAAA.[78] Much of the guide incorporated methods of selectivity, adaptation, and toxicity in their recommendations for pilots throughout the nation. For example, in the *Guide*'s introduction, the EPA insisted that effective aerial application requires "close cooperation between applicator and grower when planning a job, consideration of the effects on the environment, consideration for the safety of people, animals, and nontarget crops ... Accurate and uniform application, a competent pilot, and adherence to the planned procedure."[79]

The *Guide* also addressed some of the limitations of aerial application recognized by some of the earliest grassland pilots. Operators needed to consider correct weather conditions, explore the landscape for obstruction and study the specific contours of each field. It warned that pilots could endanger themselves as well as contaminate the surrounding area if they did not understand the difficulties "in treating small or irregularly shaped areas, and long ferrying distances."[80] Its discussion of dry, liquid, and ultra-low volume (ULV) systems aligned with many of the techniques and studies accomplished by pilots and agriculturalists in the region.[81]

Finally, the EPA's recommendations for protecting the environment incorporated the standardization efforts of the Ag-1 prototypes and the many other precautions developed by Great Plains applicators. Perhaps the most crucial of these was controlling drift. The Agency identified the same chemical and environmental factors that regional pilots, weed scientists, and farmers addressed earlier. Understanding the chemical relationships between droplet size, weather conditions, and the process of vaporization afforded pilots greater levels of safety while keeping nontarget areas from contamination.

The *Guide* reminded pilots that pesticide "spray systems cannot produce a completely uniform droplet size. Rather, they produce a range of droplet sizes."[82] Thus, to achieve the most standardized patterns, pilots needed equipment, nozzles, and techniques that accounted for variability. "Nozzle type and pressure are important factors affecting droplet size. In general, the size of droplets decrease as the size of the nozzle opening decrease or the pressure increases."[83] Another way to achieve uniformity included mixing materials with insecticide or herbicide solutions to achieve a thicker or thinner spray pattern. Just as pilots had been adding oils to aid in the dispersal and coverage process, the Agency endorsed similar techniques to reduce drift but insisted on pilot caution when employing them: “thickening agents may be added to spray mixtures to create larger spray particles. However, the airstream may break these large droplets into smaller ones.”[84] Surfacants or agents designed to reduce surface tension of liquid insecticides or herbicides can be added “to spray solutions to create smaller droplets, improve coverage and increase wetabliity of the spray.” However, if pilots mismanaged their mixture-ratios, the process could create droplets so small that they increase drift hazards.

Other precautions supported the Ag-1 program findings of the early 1950s. The *Guide* stated that pilots must “wear protective clothing and [use] equipment appropriate for the pesticide. The label on each pesticide specifies the protection required.” Pilots must also know the pesticide they are about to apply—its chemical design, toxicity studies, and field performance. Operators had to consider flagmen, farmers, and nearby residents as well as check target areas for obstructions or previous drift hazards before application—pilots should not fly in a manner “or at a time which may create a hazard—even if the customer insists.”[85]

The Chemical Age Meets the Computer Age

Throughout the 1970s, evolving views of agricultural health and environmental health continued to inform how aerial applicators, weed scientists, and farmers understood risk, safety, and toxicity. The interplay of both in the region shaped the policies and politics of chemical application at the state and federal levels. New chemicals had warranted new precautions; new pests had acquired tolerances that meant new mixing and application requirements, which in turn required new laws to guard legitimate applicators, farmers, and residents against rogue sprayers and shady chemical dealers. The computer revised these views even further.

Electronic guidance systems and new data processing systems changed pesticide application practices by merging the visions of environmental health with agricultural health—at least on a practical, regional level if not on a national, political level. Computers and the developing Global Positioning Systems (GPS), offered new ways for farmers, weed scientists, and Ag pilots to study chemical residues and resistance and practice application and farming methods that as agricultural historian Judith Fabry argues "incorporated pest-resistant plants bred for specific soil and climatic conditions, precision fertilizing, integrated pest management that combined biological and chemical controls, and specialized crop rotations and soil management techniques that minimized chemical use."[86]

Super Planes and Super Computers

In the 1970s and 1980s, many of the aviation companies built new agricultural aircraft models that attempted to strike a balance between safety, risk, and economic efficiency by aligning their aviation guidance systems with their spraying application systems. Because many of the changes in spray plane design came from the regional interactions with farm chemical landscape, these new models highlighted adaptation, selectivity, and toxicity as their main selling points—those and safety. Due partly to the new politics of the *Silent Spring* era as well as to the longer-standing relationships with pesticides in the region, aircraft manufacturers, such as Cessna (Ag Wagon), Piper (Pawnee) and Schweizer Corporation (Ag-Cat) all highlighted their Ag plane model's safety, ability to anticipate variability, and swath dispersal accuracy. These computerized reforms, they argued, kept the public and the environment safe by reducing chemical drift and environmental contamination.[87]

The central adaptation of these super planes had to do with their guidance systems. While Ag pilots still often employed flagger units, automatic devices removed ground crews from chemical swath lines. Cessna's Ag Wagon, for example, implemented a paper dispenser machine that sent out highly recognizable streamers that marked swath lines from the air. This new system also allowed pilots to increase their precision while protecting workers on the ground. Often times, as Ag pilot Jim Floyd recalled, human flaggers mistakenly went to the wrong fields or misunderstood the exact swath distances needed for each run: "originally [we] used people out there, to measure so many steps and wave a flag and they flew off of that." However, "it got to be a real hassle to get them to the field and [they were usually] not smart enough to count the steps...they posed a lot of problems. Even when we had pretty good mobile radios, they would still screw it up." Automatic flagging offered an improvement for both the safety and accuracy of swath markings but there remained inaccuracies. Floyd warned, however, that while electronic flaggers afforded pilots some advantages, the weighted streamers of "tissue and cardboard were inaccurate because they tended to move around a lot."[88]

With the advent of Global Positioning System technologies in the 1980s, pilots were able to secure swath accuracies, chemical selectivity, and anti-drift precession that earlier pilots had only hoped to achieve. Now they could process dispersal ratios and swath lines precisely in the target areas with minimal drift hazards. More advance machines by the 1990s incorporated pest and crop histories, environmental changes, and typical weather conditions for the region. Perhaps Jim Floyd put it best: “with the newer system…[aerial application] became more efficient. [GPS] is better for the farmer, it provides more even application, and it is better for the environment.”[89]

Operation S.A.F.E.

In addition to these advancements, a new safety system was being developed in the region that integrated electronic guidance systems with computerized swath studies. This new method to study application effectiveness included a spray catchment system to determine swath patterns, distribution, and drift at the particle level. Conceived by agricultural engineers L.O. Roth of Oklahoma State University, Dennis Kuhlman of Kansas State University, and Richard Whitney of NASA, Operation S.A.F.E provided a more accurate study of chemical pollution. However, it also allowed pilots to get a “real time” analysis of deposition patterns and how those changed with particle size, pesticide, and the terrain.

This Self-Regulating Application and Flight Efficiency or “S.A.F.E” system started with a field device eighty feet in length that was placed perpendicular to the path of the spray plane. It contained a series of metal bins to catch particles as well as a white paper tape and a clear film strip to show contact. Using a red fluorescent dye, according to the *Kansas Farmer*, “the white paper provides rapid readings of a spray dispersal pattern for immediate adjustment of the nozzles.

Figure 21. A Cessna Ag Wagon with the electronic paper dispenser system on the right wing. Photo taken by author in Salina, Kansas, 2009.

Figure 22. Inside a Cessna Ag Wagon cockpit. The GPS unit is on the upper left and above the joystick. The activation switch for the automatic flagger is the button on the joystick.

The film is saved for laboratory examinations at a later date that reveal exactly how much spray was hitting a given area."[90] The system evolved to include a portable computer so that results could be processed in the same day. Ultimately "Operation S.A.F.E." reflected how pesticides continued to shape the region in the computer age. One of the greatest hazards that both versions of health—agricultural and environmental—tried to protect against, in terms of aerial application, was chemical drift. This phenomenon damaged crops, contaminated fields, and it was expensive.

Figure 23. An example of a modern spray catchment system. Since the 1980s, agriculturalists have replaced the metal containers with a series of paper collectors, strings, digital photographs instead of the tape. Image taken by author in Salina, Kansas, 2009.

Figure 24. This spray pilot is participating in a 2009 University fly-in as part of Operation S.A.F.E. in Salina, Kansas. The biannual event includes testing swath coverage by spraying colored dye on paper swatches located on the ground. Image taken by the author in Salina, Kansas, 2009.

Ultimately the program explored the newest "system operating procedures, computer software development, and other technological improvements" in order to preserve the health of crops, the public, and the environment. Pilots also participated in these demonstrations to "show the professional attitude of pilots and the agricultural aviation industry, which would offset claims that pilots were wild "barnstorming crop dusters."[91]

These pesticide related challenges of the region throughout the mid-twentieth century identify the increasing divide between agricultural health and environmental health and how both influenced technological, political, and policy reforms in the 1960s and 1970s. The regional ethos of agricultural health and farmland toxicity that emerged from the protective and hazardous workings of pesticides influenced the nationalization of the agricultural spray plane, the technical and regulatory guides established for the country, and the environmental politics of the *Silent Spring* era.

Closer to home, a new criminal class of applicator and dealer also emerged as a consequence of these relationships. They were as poisonous to the health of producers and the grassland environment as pesticides. As the chemical age moved into the age of ecology and then, the computer age, pilots, farmers, and weed scientists adapted by expanding spraying schools, working with agriculturalists and government officials in standardization efforts such as the Ag-1 program, and endorsing new regulations that attempted to balance the politics of environmental health with their more practical commitment to pesticides for agricultural health.

Notes

[1] W. P. McDonald, "Problems Related to Industry—Sales," *Proceedings* (Sioux Falls, South Dak: December 6–8, 1949), 46.

[2] "Summary Panel Discussion," *Proceedings* (Winnipeg: December 9–11, 1952), 50

[3] See Thomas Dunlap, *DDT, Silent Spring, and the Rise of Environmentalism* (Seattle: University of Washington Press, 2008); Idem. *DDT: Scientists, Citizens, and Public Policy* (Princeton: University Press, 1981; Frank Graham, Jr., *Since Silent Spring* (Boston: Houghton Mifflin Company, 1970); David Kinkella, *DDT and the American Century* (Chapel Hill: University of Carolina Press, 2011).

[4] Senator Elmer Thomas, 1–2, Legislative, Box 72, Folder 28, Elmer Thomas Papers, Carl Albert Center at the University of Oklahoma.

[5] *Aviation Week*, 28 February 1949. Also see *Aviation Week*, 7 June 1948.

[6] Ibid., *Aviation Week*, 28 February 1949.

[7] Senator Elmer Thomas, 1–2, Legislative, Box 72, Folder 28, Elmer Thomas Papers, Carl Albert Center at the University of Oklahoma.

[8] "Preliminary Research Report for the Reclamation of the Non-Productive Agricultural Lands" by H. H. Bennett for Elmer Thomas' report on "The Airplane as a Farm Implement," in the Elmer Thomas Papers, Series Subject, Box 2, Folder 69, pages 1–2, The Carl Albert Center, University of Oklahoma.

[9] Ibid., 3.

[10] Ibid.

[11] Ibid.

[12] This link between health, safety, and economic efficiency is highlighted in sections two and three of Thomas' Senate Resolution 172: "Whereas there is no convenient and fully satisfactory method of measuring the distribution of agricultural materials dispensed from aircraft; a method for accurately evaluating the performance of this equipment would contribute much toward improvement of present dispensing equipment; and Whereas the present aircraft dusting, spraying, and seeding, and fertilizing equipment, and the aircraft used in such operations, being for the most part either converted military trainers, converted light personal aircraft, or obsolete biplanes, are generally dissatisfactory for those purposes. Non of the aircraft were originally designed for agricultural use, and as a consequence their flying characteristics are not satisfactory for this purpose. Present equipment for dispensing agricultural materials from airplanes does not produce sufficiently uniform distribution of these materials with the result that material is wasted and inadequate converge is obtained at the present time," Elmer Thomas Papers, Legislative Series, Box 72, Folder 30, The Carl Albert Center, University of Oklahoma.

[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] *Aviation Week*, 16 July 1951, (42); *Aviation Week*, 9 October 1950; *Chemurgic Digest*, November 1954, 6.

[17] Weick/Hansen, *From the Ground Up: The Autobiography of an Aeronautical Engineer* (Washington, D.C.: Smithsonian Press, 1998), 256; Fred E. Weick Autobiographical Transcripts, Folder 3, Tape 16 (July 1949 to August 1950), Tape 17 (August 1950 to December 1950), Tape 18 (Charlie Zimmerman's Project, Back to the Ag-1, and Texas Agricultural Aviation Conference), Accession XXXX-0425, National Air and Space Archives, National Air and Space Museum, Smithsonian Institution, Washington, D.C.

[18] Weick recollected in his autobiography that electrical lines were some of most dangerous hazards to pilots: "The testing and minor improving of the Ag-1 continued through the spring of 1951. Because many of the agricultural planes in use had had contact with electrical wires (in fact, many of the Stearmans were then showing creasing in their landing gear fairings because of contact with electrical wires and they had broken), we decided to sharpen our plane's spring steel landing-gear legs to a point, so that they could more easily break through any wires that might be contacted. In addition, we designed two fairly large sloping tubes into the turnover structure to guide wires over the cockpit, in case they slid back along the upper cowling. Also, because many airplanes had had their vertical tail surfaces catastrophically damaged by wires, we mounted a cable from the top of the cockpit to the top of the vertical fin, so that the wires would be guided over the fin and not harm it. Thus, some bad crashes were to be avoided." Also see, Weick/Hansen, *From the Ground Up: The Autobiography of an Aeronautical Engineer* (Washington, D.C.: Smithsonian Press, 1998).

[19] Weick reported in the Texas A and M *Handbook on Aerial Application in Agriculture* that "it follows, and it is now generally accepted, that a large proportion of the serious and fatal injuries associated with these crashes could be prevented by suitable airplane design coupled with the use of a suitable shoulder harness in addition to the seat belt…. It thus appears to overcome the main objections of duster pilots to the use of shoulder harness. It has been tried and apparently favorably accepted by the many pilots who have flow the Ag-1 airplane for the purpose of evaluating it (11)." See Texas A& M College, *Handbook on Aerial Application in Agriculture* (College Station, Texas: December 1956).

[20] Ibid., Texas, A&M College, *Handbook on Aerial Application in Agriculture*.

[21] Ibid., 59.

[22] Weick's recommendations in the Texas A&M handbook were reprinted in other regional aerial application manuals such as the University of Nebraska's *Handbook for the Nebraska Aerial Applicator* (Lincoln: University of Nebraska College of Agriculture, 1963).

[23] Ibid., Texas, A&M College, *Handbook on Aerial Application in Agriculture*, 60-61.

[24] Ibid, 61.

[25] R. E. Larson, "Aerial Application Techniques," in *Proceedings* (Winnipeg, Canada: December 8–11, 1952), 41.

[26] Ibid.

[27] Ibid.

[28] Ibid, 42.

[29] See Chapter 3 for more analysis.

[30] Kansas Agricultural Aviation, *KAAA Membership Directory* (1985), 34; Interview with Jim Floyd of Floyd Aero, conducted by the author at the Mid-American Air Museum, October 2010; Norman B. Akesson and Wesley E. Yates, *The Use of Aircraft in Agriculture* (Food and Agriculture Organization of the United Nations (Rome: FAO, 1974), 17–18. Also see the National Agricultural Aviator's Association webpage, "About NAAA," http://www.agaviation.org/content/about-naaa.

[31] Karl Boyd Brooks, *Before Earth Day: The Origins of American Environmental Law, 1945–1960* (Lawrence: University Press of Kansas, 2009), 112.

[32] Ibid. Also see the following FIFRA statues in the House Committee on Agriculture, House Report 80–313, 80th Cong., 1st sess. (1947), accompanying Act of 25 June 1947, ch. 125, 61 Stat. 163–173, codified at 7 U.S.C.S. 135–136y.

[33] Ibid., FIFRA.

[34] Ibid., Brooks, *Before Earth Day*, 112–117.

[35] Ibid.

[36] R. B. Widdifield, "North Dakota Weed Control Program," *Proceedings* (Sioux Falls, South Dakota: December 6–8, 1949), 26.

[37] Ibid.

[38] Robert Gottlieb, *Forcing the Spring: The Transformation of the American Environmental Movement* (Washington D.C.: Island Press, 1993), 81.

[39] Rachel Carson, *Silent Spring* (New York: Houghton Mifflin, 1962), 297.

[40] Ibid. Also see Vera L. Norwood, "The Nature of Knowing: Rachel Carson and the American Environment," *Signs* 12.4 (Summer 1987), 740-760.

[41] Ibid., Carson, 12–13.

[42] Ibid., 13.

[43] Dunlap, Thomas Dunlap, *DDT, Silent Spring, and the Rise of Environmentalism* (Seattle: University of Washington Press, 2008), 8.

[44] Nash, *Inescapable Ecologies: A History of Environment, Disease, and Knowledge* (Berkeley: University of California Press, 2006), 159.

[45] See Aldo Leopold, "The Ecological Conscience," *Journal of Soil and Water Conservation* 3 (July 1948):109–112.

[46] Carson, *Silent Spring*, 12.

[47] *Capper's Weekly*, 13 October 1945.

[48] "Spray Damage Claims" in Pesticide Registration Section Subject Files (1945-1997), Location Numbers 068-07-04-15–068-08-01-01, the Kansas State Historical Society.

[49] "Hays Air Sprayer Sees Wide Horizons for Killing Weeds by Plane," *Topeka Capital*, 20 February 1949.

[50] Ibid.

[51] "Agricultural Chemicals-Stop Sale Orders" in Pesticide Registration Section Papers (1947–1984), Location Number 067-06-01-02, the Kansas State Society; "Inspection Report #21513 'Report on Pueblo Chemical Company bootlegging of Ambush,' 09 August 1979, Location Number 68-07-05-19 in Pesticide Registration Section Subject Files (1947–1997), the Kansas State Historical Society.

[52] Ibid., “Agricultural Chemicals-Stop Sale Orders.”

[53] Ibid.

[54] See the “Kansas Chemical Spray Law, 1965,” 1–8, in the Pesticide Registration Section Subject Files, Location Number 68-07-05-19, the Kansas State Historical Society. For example, Reverend Gilbert P. Herrman, from Dodge City, Kansas—a hotbed of aerial application for wheat—wrote a letter to President Eisenhower about the problems of pesticide toxicity and chemical drift in 1953: “Mr. President my request is that there be a [national] law passed that will prohibit the free and public use of all the common deadly insecticides. Surely you must be aware of the bad effects insecticides have on our human race. We know for sure that these poison are killing insects, but is there anyone who can prove [sic] that death is limited to insects only and not to the human race? I am sure, Mr. President, that in the Government files you have more information concerning this matter than we the ordinary citizen ever hope to obtain or hear about. Nevertheless I am taking the liberty to send you some literature that may in a small way give you an idea what human health has to face…If you check the records on Cancer, Polio, Heart Disease, etc. you will find that we are getting weak rather fast, and rightly so with all the poison that is thrown at us. Any type of poison in the human system will cause, feed, or increase the above mentioned diseases [sic]. I think you can find proof for this in Government Files (1).” See Reverend Gilbert P. Herrman to President Dwight D. Eisenhower, 18 June 1953, Agricultural Research, Insecticides, Box 891, ARS, RG 310, National Archives and Records Administration.

Administration officials responded to Rev. Herrman suggesting that his worries were misplaced: “The new insecticides, such as DDT, have been investigated to appraise their hazards to animals and man more extensively than many pesticides, drugs, and industrial chemicals which have been in common use for years. We recognize that many pesticides are harmful if consumed deliberately or if *used carelessly* (emphasis mine)…We do not agree that the insecticides used as recommended are extremely dangerous as is stated in the publications submitted by Reverend Herrman (1).” See W.L. Popham to C. E. Schoenhals, 16 July 1953, Agricultural Research, Insecticides, Box 891, ARS, RG 310, National Archives and Records Administration.

The Reverend from Dodge City responded to Administration officials with an equally critical follow-up letter: “it is probably very true that, as you state ‘the only cases of DDT poisoning in man known to us is where the persons willfully or accidently ingested large quantities’ which means, I suppose, that you conclude that unless a man drops dead at once of pesticides there can be no harm from the pesticides. The question I ask is, what about those people who die a slow death as a result of the accumulation of pesticide toxicity?... Why did the government back in 1949 warn against spraying dairy barns with DDT when their studies shoed that even if only the ceilings were sprayed while the barns were empty, cows absorbed the poison and produced contaminated milk?...Please let me assure you that this is not a one man fight against pesticides. With the increase of sickness our people are getting more wise and if the government won’t act to protect their health then certainly the people of this country will. I am convinced that the enemy is breathing down our necks and we are not taking action against it. the situation is more critical than your department may think. That is why my last letter was addressed to President Eisenhower himself-perhaps he didn’t even see it or hear about it (1–2).” See Herrman to Shaw 23 July 1953, Agricultural Research, Insecticides, Box 891, ARS, RG 310, National Archives and Records Administration. (Author’s note: portion of this correspondence is quoted in Pete Daniel’s *Toxic Drift* [12–13]).

[55] Ibid., “Agricultural Chemicals-Stop Sale Orders.”

[56] Ralph McGinty to the Board of Agriculture’s Noxious Weed Division, June 1972, Board of Agriculture Collection, Box 30779, Archive Number 68-07-05-19, the Kansas State Historical Society. Also see “Agricultural Chemicals-Stop Sale Orders” in Pesticide Registration Section Papers (1947–1984), Location Number 067-06-01-02, the Kansas State Society.

[57] Bob Bunker, “Let’s Clear the Air About Aerial Application,” *Kansas Farmer*, March 16, 1968, 32.

[58] "Kansas Chemical Spray Law, 1965," 1–8, in the Pesticide Registration Section Subject Files, Location Number 68-07-05-19, the Kansas State Historical Society. For other poisoning incidents see the *Topeka Capital* reports on "Fine of $3,000 upheld against crop sprayer," 21 May 1976; "Detasseling Crew Poisoned in Field," 30 June 1978.

[59] Quoted in Joe Anderson's *Industrializing the Corn Belt*, 30.

[60] Ibid., Anderson, 30–31.

[61] Ibid.

[62] Ibid.

[63] *Wallace's Farmer*, 11 September 1970.

[64] Ibid., Anderson, 31.

[65] *Kansas Farmer*, 4 April 1970.

[66] Mr. and Mrs. G. W. Gandy, Toronto, KS to Senator Robert Dole, 15 July 1969, RG 16, Records of the Secretary of Agriculture, General Correspondence, 1906-76, Box 5080, Pesticides, the National Archives and Records Administration of the United States of America. Washington, D.C.

[67] Ibid.

[68] Ralph McGinty to the Board of Agriculture's Noxious Weed Division, June 1972, Board of Agriculture Collection, Box 30779, Archive Number 68-07-05-19, the Kansas State Historical Society.

[69] *Kansas City Star*, 28 March 1976.

[70] Ibid; Also see Lewis Regenstein, *America the Poisoned: How Deadly Chemicals Are Destroying Our Environment, Our Wildlife, Ourselves and—How We Can Survive!* (Washington, D.C.: Acropolis Books LTD., 1982), 243 [Part 2 Insert].

[71] See Jim Floyd (Floyd Aero: Aerial Application, Liberal, Kansas) to the Kansas Board of Agriculture, in "Aerial Application Letters," 11 July 1976, Noxious Weed Program Records, 067-02-03-02–067-02-04-15, Kansas Historical Society; Oral History Interview with Jim Floyd of Floyd Aero Interview, conducted by the author at the Mid-American Air Museum, October 2010.

[72] See Darle Fortmeyer (Hawkeye Spraying Service, Goodland, Kansas) to the Kansas Board of Agriculture, in "Aerial Application Letters," 12 July 1976, Noxious Weed Program Records, 067-02-03-02–067-02-04-15, Kansas Historical Society.

[73] See Frank I. Bringham to the Kansas Board of Agriculture, in "Aerial Application Letters," Noxious Weed Program Records, 067-02-03-02–067-02-04-15, Kansas Historical Society. Also see Ella and Kirk Grove of Farmers Aerial Spraying, Superior, Nebraska to the Kansas Board of Agriculture.

[74] Ibid., Bringham to the Kansas Board of Agriculture.

[75] Ibid.

[76] Robert Murphy of Murphy Aviation to the Kansas Board of Agriculture, 10 July 1976, in "Aerial Application Letters," Noxious Weed Program Records, 067-02-03-02–067-02-04-15, Kansas Historical

Society. Also see James Beaubien of Beaubien's Aerial Spraying Service (Ponca City, Oklahoma) letter to the Kansas Board of Agriculture, 12 July 1976, in "Aerial Application Letters," Noxious Weed Program Records, 067-02-03-02–067-02-04-15, Kansas Historical Society; Gilbert A. Legleiter (Aerial Spraying Service in LaCrosse, Kansas), 14 July 1976, in "Aerial Application Letters," Noxious Weed Program Records, 067-02-03-02–067-02-04-15, Kansas Historical Society.

[77] Ibid.

[78] Reade studied under Kansas' Donald Pratt in 1949. See Chapter 3 for more analysis.

[79] U.S. Environmental Protection Agency, *Aerial Application: Apply Pesticides Correctly—A Guide For Commercial Applicators* (Office of Pesticide Programs, Washington, D.C.: 1976), 2. Also see the following hazard and toxicity reports conducted by the Civil Aeromedical Research Institute: "Crash Survival Analysis of 16 Agricultural Aircraft Accidents," Report Number: FAA-AM-72-15, (Oklahoma City, Oklahoma: April 1972),1–24; "Agricultural Aviation Versus Other General Aviation: Toxicological Findings in Fatal Accidents," Report Number: FAA-AM-78-31 (Oklahoma City, Oklahoma: circa 1970s), 1–5; Paul W. Smith, "Toxic Hazards in Aerial Application," *Civil Aeromedical Research Institute Report 62-8* (CARI, Oklahoma City, Oklahoma: April 1962), 1–8.

[80] Ibid., EPA, *Aerial Application: Apply Pesticides Correctly—A Guide For Commercial Applicators*.

[81] Ibid., 2–3.

[82] Ibid.

[83] Ibid.

[84] Ibid.

[85] Ibid., 8.

[86] Judith Fabry, "Agricultural Science and Technology in the West," in *The Rural West Since World War II*, ed. R. Douglas Hurt (Lawrence: University Press of Kansas, 1998), 184; U.S. Congress, Office of Technology Assessment, *A New Technological Era for American Agriculture, OTA-F474* (Washington, DC: U.S. Government Printing Office, August 1992), 6–8.

[87] See "Crop Dusting from an Agwagon," *Kansas!* 1 (1968), 7–8; William Schweizer, *The Ageless Ag-Cat: The Forty Year History of the Ag-Cat Agricultural Airplane* (Bluffton, South Carolina: Rivilo Books, 1995); Fred E. Weick, *From the Ground Up: The Autobiography of an Aeronautical Engineer* (Washington D.C.: Smithsonian Institution Press, 1988), 307–327.

[88] Interview with Jim Floyd of Floyd Aero, conducted by the author at the Mid-American Air Museum, October 2010.

[89] Ibid.

[90] *Kansas Farmer*, 4 November 1980. Also see D.K. Kuhlman and D.C. Cress, "Aerial Application Handbook for Applicators," *Cooperative Extension Service* (Manhattan: Kansas State University, December 1981), 1–72; Vern Hofman, Art Lamey, Harvey Hirning, Mark Berge, et al., "North Dakota Aerial Spray Analysis Program," *Journal of Farm Research* 43.6 (May-June 1986), 3–39.

[91] Richard W. Whitney, "The Development of WRK Analysis Equipment and Operation S.A.F.E.," *Operation S.A.F.E. Analyst Training Class Manual* (2005), 1–5; Also see Interview with Robert Wolf by author, Spring 2011, Kansas State University, Manhattan, Kansas.

Conclusion

The current spraying guide issued by the National Agricultural Aviation Association continues to champion the notions of agricultural health, adaptation selectivity, and toxicity when applying chemicals by airplane. In *50 Ways to Treat Your Pesticides*, the NAAA recommends that pilots, farmers, and agriculturalists practice a "pesticide stewardship" when flying over fields, pastures, rangelands, and communities. "A smart aerial applicator," according to the guidebook, "will go straight to resources developed by their state pesticide safety education program coordinator. Their national or state agricultural aviation association, the EPA, the USDA or state's department of agriculture … [are] all excellent starting points that can lead to general or state-specific pesticide stewardship information on a host of topics from product, storage, transportation, and disposal to keeping pesticides on target."[1] Indeed, the ongoing workings of pesticides and their transformative interactions with agriculture, technology, and the environment from the Great Plains region continue to guide pesticide policy and aerial spraying today.[2] Importantly, aerial applicators, agricultural chemicals, and agricultural health standards remain at the center of these reforms.

The boundaries between environment, technology, and agriculture are quite blurred when it comes to the history of aerial application, agricultural chemicals, and toxicity. After World War II, the Great Plains became a chemical-agricultural landscape with pesticides acting as a keystone technology that had equal influence to the keystone species of humans. Farm poisons created their own farming spaces that manifested their influence in a host of ways—some human, some nonhuman, and some technological.

As many historians have noted, the postwar acceptance of pesticides as an agricultural panacea that “powerfully sculpted the agricultural community’s attitudes toward both pest control and government regulation” certainly informed the region’s farming and agricultural spraying throughout the mid-twentieth century. [3] Nevertheless, landowners and spray pilots constructed their own standard of toxicity and environmental risk that stressed accuracy, regulation, and a reasonable certainty of safety. Unlike at the national level, where chemical companies and organizations such as the National Agricultural Chemical Association used similar arguments against environmentalists and government oversight, farmers, applicators, and officials worked together to develop a model that on one hand challenged irresponsible applicators and demanded increased oversight for dealers while on the other hand viewed potent chemicals as the best way to protect their crops.

Finally, the politics, policies, and principles of toxicity debated in the 1960s and 1970s had regional roots. Farmers, Ag pilots, and weed scientists understood, in their own way, that chemicals, like pests, had the potential to harm. Toxicity to them included a combination of poisons—synthetic, natural, and human. An indiscriminate applicator was as dangerous as the materials he was spraying given the potential of environmental and economic damage. Pests employed their own poisonous injuries that threatened crops and livestock. Calculating chemical damage and risk could not just be about dosages or labels—contamination included violators, weeds, insects, and disease. As pilots sprayed wrong fields, dealers sold bootlegged chemicals, and weeds and insects continued to threaten the land, farmers and aerial applicators helped decide what chemical risks were acceptable in production agriculture and what practices and substances needed to be regulated or rejected. These practices and standards guided the nationalization of aerial spraying and the politics of pesticides in the 1970s and 1980s and continue to shape them today. The grasslands remain an agricultural region largely governed by insecticides and herbicides. Its farming landscape continues to highlight the obscured boundaries between chemicals, technologies, farmers, pilots, agriculturalists, pests, and the environment.

Notes

[1] National Agricultural Aviation Association, *50 Ways To Treat Your Pesticide* (NAAA: circ., 2000), 1.

[2] See "Flying Low is Flying High as Demands for Crop-Dusters Soars," *Wall Street Journal*, 14 August 2009; "Crop-dusters defy risks to help Iowa farmers increase yields, profits," *Sioux City Journal News*, 4 September 2011; "Winged technology takes scouting to new heights," *Iowa Farmer Today*, 23 February 2012.

[3] Christopher Bosso, *Pesticides and Politics: The Life Cycle of a Public Issue* (Pittsburgh: University of Pittsburgh Press, 1987), 32.

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