NATIONAL ACADEMY OF SCIENCES

# JAMES GORDON HORSFALL

*1905—1995*

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*A Biographical Memoir by*
PAUL E. WAGGONER



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NATIONAL ACADEMIES PRESS
WASHINGTON D.C.

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James G. Horsfall

# JAMES GORDON HORSFALL

*January 9, 1905–March 22, 1995*

BY PAUL E. WAGGONER

JAMES GORDON HORSFALL, who called himself a squirt gun botanist, fought the "rusts and rots that rob us, the blasts and the blights that beset us."[1] His writing inspired plant pathologists. He raised the quota of fundamental research in agriculture and the quota of agriculture in fundamental research.

## CHILDHOOD

Horsfall was born January 9, 1905, in Mountain Grove, Missouri, where his father Frank, poor as a church mouse, worked at a tiny independent fruit experiment station. He grew up in Monticello, Arkansas, where his father presided over an agricultural school. His mother was Margaret Vaulx Horsfall. The strength of the father's example was demonstrated by three sons who became a plant pathologist, an entomologist, and an horticulturist. Horsfall, claiming the essential ingredient of a scientist was nonconformity, traced his own nonconformity to a grandfather sent to shoot birds along the Mississippi river by a well-to-do English great-grandfather. Horsfall entitled his autobiography "The Story of a Nonconformist."[2] Although he would spend most of his life in the northeast, Horsfall never forgot his agricultural roots; he featured his country connections, and when he died at ninety, his will sent his library to the experiment station back home in Mountain Grove.

A pear tree afflicted by fire blight introduced young Horsfall to plant pathology, and he followed the advice to prune it. The stump left after a few years of Draconian treatment encouraged his disrespect for conventional wisdom. Father sent him to the University of Arkansas in 1921 well enough prepared to skip his freshman year.[3]

## COLLEGE

At the university Horsfall's luck continued. The fun of tinkering with Model T's had inclined him to engineering but math disinclined him. The luck was falling under the influence of Dwight Isely, an entomologist who loved science and stimulated Horsfall to love it, too. Pinning Chrysomelids into boxes for an insect collection bored Horsfall, and he later inveighed against "stamp collecting science." Riding a horse through cotton fields was more exciting. Pioneering the use of insect counts to schedule dusting for boll weevils, Isely employed Horsfall for two summers to scout the fields near Marianna, Arkansas, for signs of the weevil. His rewards of horseback riding, summer employment, and science practiced outdoors were augmented forty-eight years later when he heard from the stage of the National Academy of Sciences that he was the first scout of integrated pest management.

Horsfall claimed his nonconformity kept him from getting a graduate scholarship in entomology. The head entomologist at Arkansas had taken a dislike to him that Horsfall blamed on himself. Fortunately, however, plant pathologists H. R. Rosen and V. H. Young of Cornell found him a place and set him upon the road of the fungi. By the time he was granted a Ph.D. in 1929 he had traveled far with other students of H. H. Whetzel's *Principles of Plant Disease Control.*[4]

In 1927 Horsfall married Sue Belle Overton. Their children are Margaret Eleanor Horsfall Schadler and Anne Vaulx Horsfall Thomas.[5]

Near the end of his life Horsfall wrote of two great blunders. One was irritating the entomologist at Arkansas and the other was a remark that brought down the wrath of the head pathologist at Cornell. "Being a competitive character, my personality was pretty abrasive as a child and young man. It got me into several pecks of trouble until my wife about 1933 persuaded me that you capture more flies with honey than with vinegar," he wrote in his eighties. Sue Belle Overton redirected Horsfall's nonconformity from breaking his knuckles to breaking ground in research.[6]

### FUNGICIDES

Luckily, the Agricultural Experiment Station in Geneva, New York, gave newly graduated Horsfall a job as assistant professor in February 1929, safely before the stock market crash in October. Although the economics of 1929 may have damped his nonconformity and heightened his appreciation of the practical, he gave much credit to two greenhouse growers. They first flattered the twenty-four-year-old scientist by calling him "doctor" and then asked, "Can you soak tomato seeds in a copper sulfate solution and control damping off?" Obligingly, if insecurely, he answered, "I think so." To test his opinion he proceeded to experiment. Decades later he still recalled how the thrill from the success of the first experiment caught his mind. When he reported his success at a national meeting, the presence of the eminent L. R. Jones in the front row endorsed the thought caught in his mind.[7]

Forever after he would label himself a squirt gun botanist. In later years when administration palled, he would tell his secretary he was going to have “fun with fungicides” and slip away to his lab.[8]

Believing profoundly that institutions were the lengthened shadows of great men, Horsfall studied them. He found the man on the front row, L. R. Jones, “carried water on both shoulders.” Jones could carry theoretical epidemiology on one shoulder and cabbage breeding on the other. Vowing to emulate Jones, Horsfall found theory in something as banal as damping off. He would do both theoretical and applied research and on crops and diseases that mattered to his state.[9] Later he joined in writing, “Our philosophy is to dig new knowledge from the face of the mine and convert it to fuel to power the society that pays for our groceries.”[10]

Since P.-M.-A. Millardet in 1882 discovered that a mixture of lime and copper sulfate applied to grapes in the Medoc to discourage pilfering also discouraged downy mildew, Bordeaux mixture had been the elixir of plant pathology.[11] Deposited on leaves, it killed mildew spores when they alighted. Conforming, the new pathologist Horsfall began spraying canning tomatoes with Bordeaux, and although the dry weather of the 1930s discouraged disease and he had little disease to observe, he persisted. His genius, which he would have called nonconformity, was turning the lack of disease into opportunity. In the absence of mildew and thus the benefit of its control by spray, he could see that Bordeaux harmed the tomatoes. Remembering his vow to combine fundamental with applied, he delved into the harm.

He found that the spray of Bordeaux closed the leaf pores that admit carbon dioxide, the raw material for photosynthesis. The alkaline spray also weakened the cuticle around the pores, hardened the lamella within the leaves and stunted the tomato plants.[12]

Bordeaux was applied to far more acres of potatoes than tomatoes, and the motto was, "Spare the Bordeaux and spoil the potatoes." Horsfall could not believe that the spray stimulated potatoes but harmed closely related tomatoes. He believed the benefits of disease control, and also insect control by Bordeaux, simply hid the harm of Bordeaux to potatoes. He would find sprays that controlled the pests without harming the potatoes.

Attributing the harm to the alkalinity of the Bordeaux mixture, Horsfall tried copper oxide, but since it did not control insects as the mixture of copper sulfate and lime did, it could not succeed. Because the only chemical controls of plant disease had been sulfur, copper, and Bordeaux mixture for over a century, he was temporarily at a loss. Nevertheless, in the mid-1940s he risked excommunication by telling attendees at an inspection of fungicide trials that Bordeaux mixture on potato was a dead horse that had not yet fallen over.[13]

Despite the near excommunication Horsfall enthused in his 1945 book, "The story of organic sulfur compounds is being unfolded so rapidly that any discussion of them can hope only for a 'stop-action' snap-shot." Sulfur "wonder drugs" were in the public eye and Horsfall claimed, "Farmers are flooding the market with calls for the new 'thio' fungicides."[14] A book reviewer, however, wrote that not all would agree that Bordeaux mixture and elemental sulfurs would be turned out to pasture to spend their last years in leisure for a job well done. Thirty years later seventy-year-old Horsfall agreed that he had been an ebullient nonconformist.[15]

Fortunately, in 1945 at age forty he was unabashed. A few years earlier he had an experience on the road to Damascus. An ear infection that had endangered his small daughter was miraculously healed by a new synthetic organic compound called sulfanilamide. Undaunted by colleagues' claims that farmers would not pay $1.50 per pound for organic compounds when Bordeaux sold for 6¢, he soldiered on.[16]

A Horsfall maxim was, "Relate the unrelated."[17] Thus, he saw a similarity of sulfur in fungicidal action and in rubber vulcanization, of all things. With the help of W. C. O'Kane of the Crop Protection Institute he began collaborating with United States Rubber Company (now Uniroyal). Horsfall and his colleagues cited the dogma that copper in Bordeaux killed by oxidizing. United States Rubber replied that copper oxidizes rubber, too. So, why not try an organic pro-oxidant such as tetrachloroquinone? Accordingly, in 1938 Horsfall and colleagues treated pea seeds with it, buried the seeds, and discovered the protection imparted by what would be Spergon.[18]

A sidelight illuminated the always complicated marriage of academe and industry. Horsfall never published the results because United States Rubber would not release the chemistry, and he would not publish without it. Practicality overcame, however, and E. G. Sharvelle, then in Horsfall's lab, and H. S. Cunningham published the results under a code number. Farmers in New York State were soon buying Spergon, proving they would pay $1.50 a pound to protect pea seed.[19]

When the chemical that protected seed was sprayed on foliage in competition with Bordeaux, however, it failed. Sun and dew caused it to hydrolyze. Although related quinones did not deteriorate and found commercial application, they did not find it on potatoes.[20]

In 1939 Director W. L. Slate of the Connecticut Agricultural Experiment Station persuaded Horsfall to move to New Haven to succeed G. P. Clinton (and before him Roland Thaxter) as chief of the Department of Plant Pathology and Botany. Although both predecessors had been distinguished, Horsfall mainly enjoyed quoting Thaxter, demonstrating his own lively writing, and exposing Thaxter's acidic wit.[21] He found a comfortable home at America's first agricultural experiment station, whose founder believed, "Theory and practice must march together."[22]

In the same year Horsfall sat in a cheap restaurant outside Grand Central Station talking with his friend D. F. Murphy of Rohm and Haas Company about their cooperative work on cuprous oxide. Perhaps because he had changed addresses Horsfall felt it was time for other changes. He said to Murphy, "Let us try to develop organic fungicides. Sulfur is a fungicide. Let us try organic sulfur compounds."

Obligingly, Rohm and Haas sent 100 samples in January 1940. One was He-175, later labeled D-14. A. E. Dimond and J. W. Heuberger with Horsfall found D-14 was water soluble and so spread an invisible film evenly over leaves. When it dried, however, it became insoluble and, hence, resistant to removal by rain. It had a peculiar dosage-response curve, it controlled several diseases, and its invisible film recommended it to the eye.[23] D-14 is ethylenebisdithiocarbamate or nabam.

Soon, modifications of nabam (i.e., zinc and manganese ethylenebisdithiocarbamate) by Heuberger, D. O. Wolfenbarger, R. W. Barratt, and Horsfall completed the invention of successful controls of a range of diseases. Although the control of potato and tomato late blight by nabam had at first disappointed, the alterations of solubility by zinc and manganese saved nabam from almost certain failure, and Horsfall could later write, "A potato fungicide was born, and Bordeaux was in trouble."[24] About forty years later the National Research Council reported about the family of ethylenebisdithiocarbamates (EBDCs):

> There are over 40 manufacturers world wide . . . EBDCs are the

most widely used group of fungicides in the world. The global market was estimated at $525 million in 1984. In the United States, more than 30 million pounds are used annually to control a wide variety of fungal diseases . . . Approximately one-third of all fruits and vegetables in the United States are treated with EBDCs.[25]

## BORDEAUX MIXTURE DIED AND FELL OVER

Fungicides that lie in wait on leaves cannot control fungi like the Dutch elm disease pathogen, that an insect injects into the host. When Horsfall arrived in New Haven, the disease was decimating the trees that had given it the name Elm City. Joined by G. A. Zentmyer and A. E. Dimond, he tried chemotherapy, putting the fungicide into the water-conducting vessels of the elm where the pathogen lived. Rarely had systemic fungicides been tried, and it took a nonconformist to imagine he could save a tall elm. Undaunted, the team filled Cremo Ale cans with candidate elixirs and injected the fluid into the vessels inside the trunks by connecting ale cans to trunks with rubber tubes.[26]

The campaign to save the elms failed. Although trees alive were kept alive, they died as soon as treatment stopped. Horsfall attributed the failure to degradation of the compounds in the tree plus the lack in plants of the analog of phagocytes to clean up survivors. A consolation to the campaigners was Ainsworth's statement in a history of plant pathology that their unsuccessful attempts to control elm diseases by chemotherapy provided a stimulating example to others. In 1968 others finally discovered a successful systemic fungicide, benomyl.[27]

## EXPERIMENTER

Horsfall believed in saving energy by using other people's data to draw new conclusions and applauded the plant pathologist who boasted none of his books had any experimental data of his own collecting.[28] Horsfall's generalizations could leave the listener awestruck. When a critic observed, "He leaps from crag to crag with the nimbleness of a mountain goat," Horsfall liked that.[29] Nevertheless, he was a shrewd experimenter.

To anticipate fungicidal success in the field he designed an apparatus for uniform deposit of fungicides on a glass slide and measurement of their action on spores.[30] His 1945 book, which found its way into several languages, featured dosage-response curves on logarithmic-probability coordinates for exploring the laboratory results. In an era dominated by randomized blocks and Latin squares of treatments in the field, he cleverly tested fungicides on spiral rows: "The hand-carried spray boom is flexible, the power pump untiring; the circular route of travel saves a return empty trip; and the water supply and drainage arrangements save work and time in loading."[31]

## EPIDEMIOLOGY

His preeminence in fungicides could obscure Horsfall's contributions to epidemiology. In 1932 he coined the term "inoculum potential" to convey the idea of mass action—the greater the mass or virulence of the pathogen present, the more severe the disease regardless of environment. During the decades since, the precise meaning of inoculum potential has been smudged, with environment sometimes included and sometimes not. Through it all, however, Horsfall's graphic phrase on the banal dusting of tomato seed continues to convey the notion that an abundant supply of fungus can overwhelm a partially effective control.[32]

Determining the effectiveness of a fungicide brought Horsfall to the crux of epidemiology: How much disease is there? Measuring the changing quantity of disease in a crop of countless leaves requires a balancing of efficiency and accuracy. Without efficiency, the disease will out-race its measurement. Without accuracy, differences cannot be discovered. By 1942 Horsfall found that visually lumping plants into four equal grades of 25% each served fairly well.[33] By inverting the issue from one of seeing disease to one of what disease could be seen, however, Horsfall improved estimation.[34] "We stumbled onto two principles: (1) that the human eye is a photocell that reads in logarithms according to the Weber-Fechner law of human acuity and (2) that the eye reads the amount of diseased tissue below 50% and the amount of healthy tissue above 50%."[35] Decades later, fearing pathologists were spending too much time on minutiae while neglecting larger matters, Horsfall wrote, "Many pad around in air-conditioned laboratories seeking the third decimal place in disease physiology. Very few tackle the blue-jean job of searching for accuracy in disease appraisal. Suppose for a few years now we give triple credit toward promotion for the disease appraisers."[36] And another decade later, the Horsfall-Barratt grading system was still alive and a citation classic.[37]

The epidemic being assessed marches through a population of plants, integrating many factors in the environment and characteristics of the pathogen and host. This fabulous array boggles the mind. The arrival of fast computers, therefore, invited the integration of experimental evidence about the components of epidemics with mathematical simulators. They invited computation to reveal the controllable steps and also forecast epidemics. Accordingly, Horsfall participated in the review of knowledge of the life cycle and environmental influences on a tomato blight, experimented to fill in gaps, and assembled the first mathematical simulator of a plant disease. Histories of past weather and disease had been converted into statistical rules for forecasting disease, but the simulator EPIDEM was the first attempt to assemble physiological experiments on the components of the pathogen life cycle into a model that marched ahead as a virtual epidemic. A relative, EPIMAY, allowed forecasts of a new disease without a history, Southern corn leaf blight.[38]

Besides his own contributions to epidemiology, Horsfall inspired those of another. Collecting authors for a treatise on plant pathology, Horsfall invited the relatively unknown J. E. van der Plank in the Department of Agricultural Technical Services in far-off Pretoria, South Africa, to write a chapter, "Analysis of epidemics." Impressed by the chapter, Horsfall introduced van der Plank to his publisher. The outcome, *Plant Disease Epidemics and Control*,[39] taught plant pathologists how to interpret the logistic progress of an epidemic in terms of compound and simple interest, infection rates and latent periods, and horizontal and vertical resistance. Van der Plank inscribed a copy of this book, which transformed plant epidemiology, "To J. G. Horsfall, who with A. E. Dimond, started this in July 1957."

## THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION

Back in 1939, when Horsfall left Geneva, New York, for New Haven, Connecticut, he went from one experiment station to another. At the Connecticut station, however, he took up the tradition of the first of the American laboratories that S. W. Johnson named by translating *Landwirtschaftlich Versuchsstation* from the German. A student first of B. W. Silliman at Yale and then of J. von Liebig in Germany, Johnson spent a lifetime thinking, demonstrating, and writing how science and practice could most effectively march together.

After leading the plant pathologists in New Haven for nine years, Horsfall in 1948 became the fifth director of the Connecticut station and thus Johnson's successor. Ever the student of great men, Horsfall made Johnson's letters[40] his guide as he led an agricultural station "near but not part of the local university"[41] for twenty-three years as universities ballooned and farmers dwindled.

He eschewed the ambition to grow, saying "We don't want to be the biggest experiment station, just the best."[42] He spoke frequently of the "station charter," the Connecticut general statute establishing the station. He maintained the sanctity of an independent board of politicians, scientists, and farmers controlling the station and directly reporting to the state legislature. In an analog of priestly celibacy, he discouraged consulting and lecturing routine college courses to encourage concentration on research.[43]

Nevertheless, Horsfall knew people beyond the dwindling population of farmers had to support the station. When he had to make a difficult choice, he said he justified it to three imaginary state legislators, mostly urbanites, seated on the couch in the director's office.[44]

The gypsy moth and DDT presented a supremely difficult choice. The imported pest had been defoliating expanding areas of forest in Connecticut since the beginning of the twentieth century. The miracle of DDT and airplanes at the end of World War II presented to some a blessed opportunity to eradicate the pest; however, Horsfall and his colleague, state and station entomologist Neely Turner, who controlled aerial spraying, believed eradication was a phantasm. They would not lend their authority to federal authorities who wanted to spray the state. They received the encouraging support of the *Hartford Courant,* which editorialized, "If necessary, let us call out the [Governor's] Foot Guard and the Horse Guard to repel further forays by federal authority, even if it comes armed with DDT."[45] Horsfall lived to see a biological control of the gypsy moth discovered by station scientists.[46]

Even sooner, however, environmentalists understood that

Horsfall opposed heavy handed measures, and in 1962 Rachel Carson quoted approvingly his colleague state entomologist Turner.[47] Still earlier, the mayor of Meriden was pressured to ask Director Horsfall to approve the aerial spraying of his city with dieldrin. Horsfall replied, "First, that dieldrin was a pretty poisonous substance; second, that it would fall on babies and children playing outdoors; third, that it would fall on any cat caught out of doors; fourth, that the cat would lick the dieldrin from its fur and poison itself; and finally, that if the mayor would sign a letter to me and say, 'Let us spray,' I would approve." Horsfall never heard from the mayor.[48]

At the same time, obsessive fears of pesticides, of course, appalled the inventor of fungicides. He suffered picketing by the fearful. He drafted an editorial comparing them to Chicken Little, but wisdom and colleagues convinced him to leave it unpublished.[49]

In the end, leaders esteemed Horsfall's combination of a farmer's view of nature with a dislike of excess. When President John F. Kennedy set up a committee to confer with Rachel Carson, he appointed Horsfall to serve.[50] In 1970 Governor John Dempsey of Connecticut selected Horsfall to lead his Committee on Environmental Policy. Before he allowed the committee to recommend action, Horsfall led the members on a thorough diagnosis of societal functions that caused environmental problems. "In that way . . . haste for action could be tethered until we had a better diagnosis of causes on which to prescribe."[51] The consequent recommendations caused, among other things, a thoroughgoing revision of the way the Connecticut government dealt with parks, forest, water, and, broadly, the environment. It also led to a program of purchasing development rights on farmland. Recognizing his contributions to the state environment, the *New Haven Register* designated Horsfall Connecticut Citizen of the Year for 1971.[52] Director Horsfall had broadened the station's field from farms to the whole landscape.

### FUN WITH WORDS

In an autobiography Horsfall ranked "fun with words" with "fun with fungi" and wrote of his style: "Being a nonconformist, I have always tried to say it differently. I could never abide the stodgy stilted style of much scientific writing. The English language is an elegant medium for saying exactly what one wants to say—no need to use any of the standard circumlocutions."[53] In college he edited the student magazine, and by age forty he had published *Fungicides and Their Action* (1945). During the 1950s he and A. E. Dimond edited *Plant Pathology, An Advanced Treatise.* A score of years later, Horsfall and E. B. Cowling edited *Plant Disease, An Advanced Treatise.*[54] In the five volumes of the 1977-80 treatise he recurred to his theme of pathometry, indulged his hobby of genealogy, and concluded with a pithy philosophy of plant pathology.

During the 1950s up to 1962, Horsfall led committees of the American Phytopathological Society and Annual Reviews, Inc., that labored to create journals for synthesizing the knowledge about plant disease. The sensible and enduring result was the birth of a single journal, the *Annual Review of Phytopathology.* [55]

In 1973 Horsfall retired from the directorship of the Connecticut Agricultural Experiment Station and assumed the title of Samuel W. Johnson distinguished scientist. As an octogenarian Horsfall wrote the history of the pioneer experiment station, an invention for making inventions.[56]

### THE NATIONAL ACADEMY OF SCIENCES AND SCIENCE POLICY

In 1953 the National Academy of Sciences elected Horsfall a member. His two brothers were scientists, too, and he wrote, "As a child, sibling rivalry played a role, I am sure."[57] He welcomed the honor of membership as he later welcomed other awards of distinction, perhaps in a continuing competition. Mostly, however, he welcomed the election as a route to affecting scientific policy. He believed a scientist should "carry water on both shoulders" because in President John F. Kennedy's words to the Academy, "Scientists alone can establish the objectives of their research, but society, in extending support to science, must take account of its own needs."[58]

During the 1950s and 1960s Horsfall served on committees of the Atomic Energy Commission and National Aeronautics and Space Administration, the President's Science Advisory Committee, and the National Advisory Commission on Food and Fiber. He served on the Academy's Latin-America Science Board, and he led its Board on Agriculture and lobbied for a commission on agriculture and renewable resources.[59]

Discerning an excessive emphasis on application during his early years as a scientific statesman, he urged more basic research. Later, however, he perceived a growing separation of science and application, which violated the maxim that theory and practice must march together. He made his case in an unforgettable essay, "Relevance: Are we smart outside?"[60] He related the parable of the little boy who was asked why he couldn't do as well in school as Alice. The boy answered, "Mother, Alice may be smart in school, but she is awfully dumb outside." To a scientist, who in 1932 searched out distinguished biochemist Z. I. Kertesz to join in studying "some effects of root-rot on the physiology of peas,"[61] basic research was holy. But four decades later he worried about irrelevance, deplored grantsmanship, and wrote, "Basic research at the old stand will no longer sell."

He urged his colleagues to fire up their relevancy, raise their quota of field research toward 50%, and give credit for publication of practical results.

As good as his word, Horsfall led committees at the Academy in two relevant inquiries. In 1970 an epidemic swept over the corn crop of the United States, threatening a great resource. In some sense, science and the technology of plant breeding were responsible because their success had caused genetic homogeneity of the crop. “In that it is the responsibility of the Agricultural Board [of the Academy] to watch for perturbations in the nation’s agriculture and to suggest means by which to reduce them, the board established a committee to examine the blight epidemic.” Horsfall led the committee of plant breeders, pathologists, entomologists, economists, and people knowledgeable in major crops to investigate the circumstances and also the more general issue of genetic vulnerability.[62]

When his colleague C. R. Frink called his attention to a slower rise of farm efficiency in the 1960s than in the previous decade, Horsfall encouraged the Rockefeller Foundation to fund a commission on agriculture and renewable resources of the Academy to perform an investigation of the nation’s agricultural production efficiency. While Horsfall was leading the investigation, both food prices and exports soared, showing his prescience in anticipating the need of a nation that had been basking in sunny surpluses. Nevertheless, the report concluded optimistically that breakthroughs in cell fusion, photosynthesis, and biological nitrogen transformations could restore abundance. After the tally of basic breakthroughs hoped for, the last phrase of the report showed Horsfall’s hand: “Being ever mindful of the need to seek practical field applications of major advances in knowledge.”[63]

Happily the Horsfall clan of James, Sue Belle, daughters, and engineer sons-in-law were close knit. They shared a retreat on Lake George where an octogenarian could teach grandchildren such technology as repairing screen doors.

Horsfall channeled his proclaimed nonconformity into plant diseases and policy and wore a tie. He invented fungicides. He broadened the charter of his experiment station to encompass the whole landscape. He died a few weeks after his ninetieth birthday and was buried in New Haven's Grove Street Cemetery near the father of American experiment stations. They shared the belief that theory and practice must march together.

## NOTES

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3. P. E. Waggoner (PW). Memo dated October 1, 1984, of conversation with Horsfall.

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7. Story of a Nonconformist, pp. 5-6.

8. Recollection of Lois Pierson.

9. Story of a Nonconformist, p. 16. Years later at the Connecticut Agricultural Experiment Station, Horsfall persuaded his colleague H. B. Vickery that science would be served as well and politics better if he pursued his studies of amino acids with a Connecticut crop: tobacco (told to PW by Horsfall).

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