Southern Regional Extension Forestry
A Regional Peer Reviewed Publication
SREF-FM-010 (Also published as Texas A & M Publication 805-124)
March, 2007

Pesticide Development

a Brief Look at the History

Eric L. Taylor, Assistant Professor & Extension Specialist, Texas Cooperative Extension
A. Gordon Holley, Assistant Professor of Forest Economics, Policy, and Management, Louisiana Tech University
Melanie Kirk, Extension Program Specialist, Texas Cooperative Extension

Although the history of pest control likely began with the first human who swatted a mosquito or picked off a tick, it was not until the emergence of organized agriculture, when pests attacked the plants we grew for food and threatened our very own survival, did the battle for the control of our planet begin. Today, we have far more uses for pesticides. They are essential to the efficient use of our natural resources. In fact, the overall high standard of living in the US (e.g., abundant food, clothing, and affordable housing) would not be possible if not for pesticides. Pesticides are not without some risk however, but the many benefits are too often taken for granted. Consider for a moment, that we (society) accept a total and complete ban on the use of pesticides without regards for the advantages they provide, then we must be willing to accept soaring food and fiber shortages, wood shortages, and outbreaks of long-forgotten human and animal diseases.

Just as the benefits of pesticides are real, so are the potential disadvantages. Although research and education constantly produces safer-to-use chemicals, pesticide misuse and accidents still occur. These incidents add to the negative public perception about pesticides, and fuels political debate. For these reasons, pest control methods and pesticide usage should always be something we strive to improve. At the same time, we must be careful to base policies and regulation on facts and logic and not false perceptions and misinformation. The goal of this publication is to list key events in the history of pesticide development. It should serve as a framework to support other pesticide publications specific to forestry. After all, there are always lessons to be learned from history.

What is a Pesticide

The U.S. Environmental Protection Agency defines pesticides as:

> "*Any substance or mixture of substances intended for preventing, destroying, repelling, regulating, or controlling pests*."

Simply put, pesticides are chemicals that we use to kill unwanted organisms – be they anything from insects to plants. In nature there is really no such thing as a pest, but humans have labeled any organism that endangers our food supply, health, or comfort as a pest. In a forest ecosystem, we consider a pest any organism that competes with the productivity of the desired forest crop or amenity. Examples of pests include insects, unwanted plants (or weeds), gophers and other animals, and disease.

There are many types of pesticides. The most common classes of pesticides include:

- *Fungicides* - pesticides that kill fungi (including blights, mildews, molds, and rusts),
- *Herbicides* – chemicals that severely interrupt a plant's normal growth process,
- *Insecticides* – pesticides designed to kill insects and other arthropods.

Other major classes of pesticides also include:

- *Algicides* – pesticides used to control algae in lakes, swimming pools, and water tanks,
- *Antifouling agents* – chemicals that repel organisms that attach to underwater surfaces,
- *Antimicrobials and biocides* – chemicals that kill microorganisms such as bacteria, fungi, and viruses

- *Disinfectants and sanitizers* – chemicals used to disable disease-producing microorganisms on inanimate objects,
- *Fumigants* - a gas or vapor intended to destroy pests in hard to reach areas such as the interior of buildings or soil,
- *Miticides* – pesticides designed to kill mites that feed on plants and animals,
- *Molluscicides* – pesticides used to kill or repel snails and slugs,
- *Nematicides* – pesticides that kill microscopic, worm-like organisms that feed on plant roots (nematodes),
- *Ovicides* – chemicals used to kill eggs of insects and mites,
- *Piscicides* – chemicals for the control of fish,
- *Repellents* – chemicals that repel pests such as mosquitoes or animals, and
- *Rodenticides* – pesticides used to control mice and other rodents.

Care must be taken to use the proper terminology when communicating with others. Far too often these terms (especially herbicides and pesticides) are incorrectly or mistakenly interchanged fueling confusion and distrust.

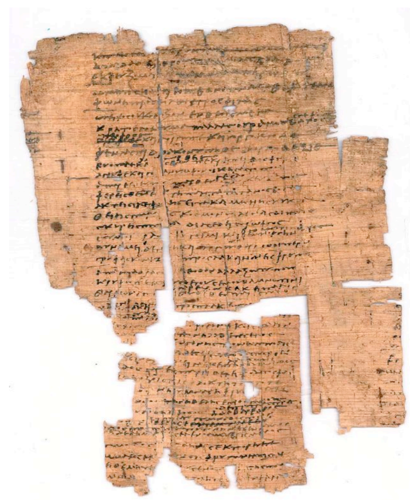
Common Household Pesticides

In the US, pesticides are commonplace in our homes. Many might not realize the number of pesticides commonly found in the average household. In fact, 85 percent of all homes have some kind of pesticide in storage. Amazingly, homeowners use roughly the same amount of insecticides in and around the home as farmers use for food production. Some pesticides commonly found in homes across the nation include:

- Antibacterial Soap
- Bathroom and kitchen sprays that kill or prevent mold and mildew
- Flea and tick spot-on application (e.g., Advantage™ and Frontline™), pills (Program™), sprays, powders, and collars
- Kitchen, laundry, and bath disinfectants,
- Lawn and garden treatments
- Mosquito repellents
- Roach sprays, foggers, and baits, and
- Various rodent poisons

Pesticide Use in Ancient Times

Pesticides are by no means a new invention. The first recorded intentional use of a pesticide dates back to 2500 BC when the Sumerians rubbed foul-smelling sulfur compounds on their bodies to control insects and mites in belief that the stench would repel the pests. Ancient Egyptians also experimented with pesticides. The Ebers' Papyrus, the oldest known medical document (dated around 1550 BC) describes over 800 recipes, many containing recognizable substances, that were used as poisons and pesticides.



The Ebers Papyrus written by Egyptian alchemists in 1550 BC.

In Greece, Homer described how Odysseus "fumigated the hall, house and court with burning sulfur to control pests" around 1000 BC. About the same time, the Chinese were using compounds made from mercury and arsenic to control body lice. The Chinese at this time had already been using predatory ants to protect citrus groves from caterpillars and wood boring beetles. They even used ropes or bamboo sticks tied between adjacent branches to help the ants move easily from place to place – perhaps the earliest form of Integrated Pest Management (IPM). Man's concern with disease is evident in the Old Testament (First Kings 8:37) that lists blights and mildews as among the great scourges of mankind. In approximately 300 B.C. Theophrastus, considered the father of modern botany, was the first to write about various pests damage. He reportedly killed young, undesirable trees by pouring olive oil on their roots. He also noted that certain weeds were associated with specific crops. Soon after, Cato, a Censor of the Roman state who lived from 234 BC to 149 BC, advocated the use of a spray made from the oils of the hellebore plant to kill rodents and insects.

During this time, the Romans became so distressed over grain crop losses due to rusts that they created a special rust god, Robigo, to which they sacrificed rust colored animals such as dogs and sheep each spring.

Marcus Terentius Varro, known in his time as the most learned of all the Romans, is credited with discovering the first chemical weed killer in the first century B.C. He noted that amurca made from crushed olives was toxic to ants, moles, and weeds. He also spuriously noted that whenever amurca seeped from olive oil presses onto the ground, the ground became barren, although this was likely due to the addition of salt to the olives before they were pressed. In any case, Varro began recommending amurca application for all noxious weeds.

Ancient olive press at Irtem, Morocco (by Mark Horrell).

Amurca was the base ingredient for many pest remedies. It was usually boiled in copper vessels and often mixed with salt. Both copper and salt have pesticidal properties. Amurca was used to fight insects as well as weeds. Palladius wrote of mixing amurca and extracts of cucumber or lupins spiked with urine to repel caterpillars from cabbage. Romans used burning sulfur to control insects and applications of salt to control weeds. In 800 A.D., the Chinese used a mixture of arsenic and water to control insects in fields and citrus orchards.

Pesticides have existed for centuries although progress in pest control had been minimal until more recent times. For example, there was very little progress in pest control during the dark ages, when ignorance and superstition thrived. With the Renaissance, however, people began to view pests less as a punishment from God and more as members of a natural world that could be studied, understood, and controlled. As a result, the Renaissance brought more accurate observations of the natural world. This in turn led to more inventive control practices.

For example, rotenone was used as early as 1649, in South America, to paralyze fish, causing them to surface. Rotenone is obtained from the roots of several tropical and subtropical plant species belonging to the genus *Lonchocarpus* or *Derris*. About the same time, extracts of tobacco were being used to control lacebugs on pears.

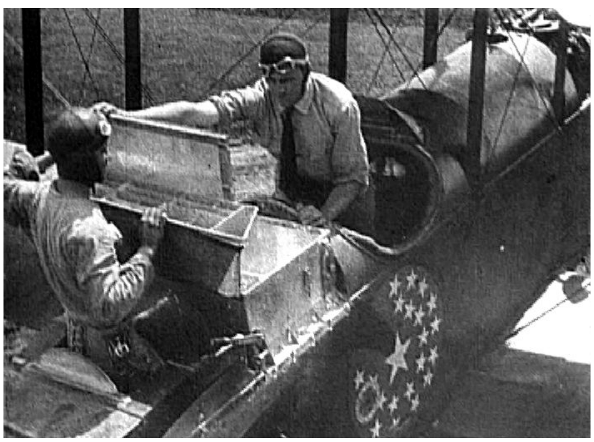
From the time of 1750 to about 1880, Europe would experience an agricultural revolution. During this time, crop protection became more wide spread and international trade promoted the discovery and use of the insecticides *pyrethrum* and *derris*. This was the same time that books and papers devoted to entirely pest control started to emerge. Rotenone would once again become popular as an insecticide to control leaf-eating caterpillars. By the start of the 19th century, scientists had a better understanding of fungi, and in 1807, used a copper sulfate solution to control bunt disease in wheat. Paris green, developed in 1867 from a copper & arsenic mixture, was used extensively to control the potato beetle and protect grapes from insect damage.

Late 19th Century dusting of a potato crop with Paris Green.

During the 19th and early-20th century, Europe and the U.S. used dilute sulfuric acid, iron sulfate, copper sulfate (blue vitriol), copper nitrate, and sodium arsenate to control broadleaf weeds in cereal crops. In 1885, a mixture of hydrated lime and copper sulfate (known as "Bordeaux mixture") was used to control downy mildew on grapes. Bordeaux mixture is still one of the most widely used fungicides around the world. Pyrethrum, a natural insecticide made from the blossoms of various chrysanthemums, was used as a louse powder. Even petroleum oils were used to control weeds in ditches and on carrot crops.

In 1880, the next step came when the first sprayers allowed pesticides to be delivered in a mist of fine droplets. Older formulations like Paris green quickly fell out of favor to be replaced with cheaper formulations like lead-arsenate. Soon after, in 1896, the first selective herbicide, iron sulfate, was found to kill broad leaf weeds. 1913 saw the introduction of organic mercury compounds to protect seeds from rust and other diseases. These treatments became routine until the 1960s when all mercury-containing pesticides were removed from the market due to its toxicity to humans.

As pesticides became more effective, farmers dreamed of dispersing them from the air to efficiently treat large areas. However, the first aerial application of an insecticide was not until 1921 when Ohio farmers battled the catalpa Sphinx Moth. Pilots dropped lead-arsenate dust in heavily modified airplanes. Agricultural chemical companies quickly saw the future. Fields could now be sprayed quickly and efficiently from the air.



The first aircraft modified for the application of lead-arsenate.

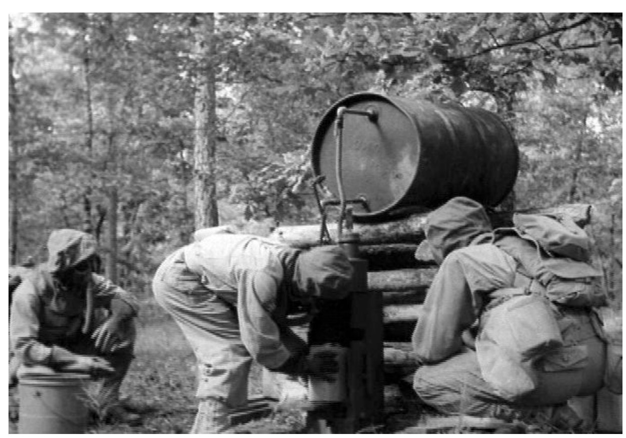
Modern Pesticides

In 1934, the fungicide, thiram, was developed which led to the development of a series of effective and widely used fungicides over the next ten years. Swiss chemist, Paul Müller, developed a new compound in 1939 that would profoundly change the lives of farmers and people around the world. Müller discovered the insecticidal properties of DDT (dichlorodiphenyltrichloroethane), an innovation that later earned him the Nobel Prize. He demonstrated that DDT killed the Colorado potato beetle, a pest that was ravaging the potato crops across North America and Europe.

DDT, the first synthetic organic chemical for selective control, quickly became the new "wonder insecticide". The compound was credited for saving thousands of lives during World War II by killing typhus-carrying lice and malaria-carrying mosquitoes. In the years to come, however, this product of the 30s would go from savior to scourge.

1940's advertisement emphasizing the "Great Expectations Held for DDT." (Killing Salt Chemicals)

DDT was eventually banned, but it opened up a long line of new organic chemical insecticides that would change agriculture, and the stage was set for developments in the succeeding decades. In fact, World War II served as a spring-board for the modern agricultural-chemical industry. The chemicals and technologies initially developed for warfare during that era were later rerouted for use on farms. For example, German scientists experimenting with nerve gas during World War II synthesized the organophosphate insecticide parathion. It was first marketed in 1943, and to this day, parathion is still widely in use. World War II marked the scientific age of pesticides for it gave us DDT, BHC, Aldrin Dieldrin, endrin and phenoxy herbicides such as 2,4-D; 2,4-DP (1944); and 2,4,5-T (1945).



WW2 use of the organophosphate, parathion.

Throughout the 1950s and 60s, these types of chemicals became major pest control agents. This decade is often called the era of the organophosphate poisons. Malathion was introduced by American Cyanamid Company in 1950. Herbicides atrazine, paraquat, and picloram were developed in 1958, and 1960. Suddenly, it became all too common for people to apply huge amounts of these chemicals in an attempt to "sterilize" habitats from pests, creating ecological havoc. Rachel Carson, in 1962, penned her seminal work, *The Silent Spring*. The book was the first widely read warning of pesticide overuse. Although many consider it factually questionable, *The Silent Spring* was a landmark challenge to the abuse of synthetic pesticides and initiated the movement toward agrochemical regulation that is still in fierce debate today.

One of the greatest strengths of these early chemicals of broad-spectrum activity also became one of their greatest weaknesses. While it is certainly an advantage to control multiple pest species with a single chemical treatment, the non-specificity of most early pesticides also killed the beneficial organisms and natural enemies of the target pests in high numbers. This had an enduring impact on ecological balance in the absence of biocontrol agents (that is natural enemies and competitors), more insecticide applications are often the only recourse available to stop pest resurgence.

Another unforeseen problem with early, modern pesticides and spray practices is that some pests became genetically resistant to pesticides under the constant chemical pressure. Insects are among the most adaptable organisms on the planet. For the past 400 million years they have managed to survive by rapidly adjusting to changes in their environment, therefore it is no surprise that they could also adapt to chemical pesticides. Resistance has increased exponentially since the late 1940's, and today, there are over 500 pest species that exhibit some level of resistance to at least one type of insecticide.

Perhaps more significant, pesticide residues began to appear in unexpected biological systems. The early, modern chemicals were developed from environmentally stable compounds. They were found to accumulate in the body fat of non-target organisms. Predators, particularly those at the top of a food chain, started to amass high pesticide concentrations as they fed on the primary and secondary consumers of the target pest. This process, known as bioaccumulation (or biomagnification), was responsible for high levels of DDT and related compounds in birds of prey during the 1960's and 1970's. These pesticides did not injure the birds themselves, but caused thinning of their egg shells and high rates of breakage during incubation. For this reason, most organochlorine compounds (e.g., DDT) were banned during the 1970's and 1980's and many of the threatened bird species are now recovering from the brink of extinction.

Ibis eggs affected by DDT bioaccumulation.

Finally, in some cases, sub-lethal concentrations of an insecticide can stimulate rather than suppress the growth of a pest population. This phenomenon, known as *hormoligosis*, has been observed in a number of pest species. Low doses of pesticide actually seem to improve the nutritional quality of host plants, thereby increasing a pest's reproductive potential or decreasing its time of development.

Integrated Pest Management

The late 1960s and 1970's saw the re-introduction of the concept of IPM - Integrated Pest Management. The term was introduced by R.F. Smith and R. van den Bosch in 1967. However, IPM was not really a new concept. It was commonly practiced in the years before synthetic organic insecticides became widely available. But the old ways were largely abandoned after World War II because chemical control was so effective, convenient, and inexpensive. Once we recognized the dangers of over-dependence on a single control strategy, the principles of integrated pest control gained renewed acceptance.

IPM is a way of thinking that strives to *manage* insect pest population instead of attempting to completely eradicate the pest. IPM aims to keep pests at economically insignificant levels by using crop production methods that discourage pests, encourage beneficial predators or parasites that attack pests, and timing pesticide applications to coincide with the most susceptible period of the pest's life cycle. However, IPM requires more effort because it requires an understanding of ecological principles and a thorough knowledge of the pest's life cycle and population dynamics.

This renewed ideology paved the way for the development of "softer insecticides" that were less harmful to beneficial insects and the environment. In addition, much research was conducted to develop pesticide materials that would be effective at low rates (1 oz/active ingredient per acre rather than 2 lbs.). During this time, we saw the widespread banning of DDT (1970s). The herbicides glyphosate (1971- Roundup, Rodeo), triclopyr (1975- Garlon, Grazon, Remedy), haxazinone (1975 - Pronone, and Velpar), imazapyr (late 1970s - Arsenal®, Chopper®, Contain®) and metsulfuron (1983- Escort®, Ally®) were developed and are still commonly used today.

The 1990's took the IPM concept to the next level by focusing in on development of bio-rationals. Bio-rationals are pesticides that are based on some type of naturally occurring, biological insect hormone or venom, microbes, or plant material extracts. These materials are then synthetically reproduced to produce pesticides. Many of today's pesticides are designed from bio-rationals. For example, 1972 saw the release of Bacillus thuringiensis (Bt) and pyrethroid insecticides.

Consumers now have multiple choices of synthetic pesticides.

BioTechnology

This discussion would not be complete without mentioning biotechnological advancement made in the agricultural world. Biotechnology, or genetic engineering, can be used to modify the genetic compositions of plants, animals, and microorganisms. Currently, the technology is used primarily to modify crops, although other applications are constantly being development. Some of the most important commercial applications of biotechnology include advancements made in herbicide tolerant, insect tolerant, and virus tolerant crops.

Summary

In summary, today's pesticides are designed to persist for shorter periods in the environment and are less lethal than the early days of lead arsenate and DDT. Furthermore, the complexity of modern IPM programs will continue to increase as we add more knowledge about pests, develop new management tactics, and learn how to optimize existing control strategies. Integrated pest management is also a major component of Sustainable Agriculture whose goal is to satisfy human needs for food and fiber while preserving nonrenewable resources, protecting environmental quality for future generations, and safeguarding the profitability and long-term viability of commercial agriculture.

U.S. Forest Herbicide Timeline

(adapted from a presentation by R.G. Wagner)

1929 The first reference to herbicide appears in U.S. silviculture text (Hawley 1929)

1937 Fourth edition of the *Practice of Silviculture* indicates injecting sodium arsenite more effective for controlling unwanted trees than felling or girdling

1950s Herbicides began to be used to control woody plants on non-agricultural land. First herbicide applications to wild landscapes to improve forage for grazing animals.

1954 Five pages devoted to herbicides or silvicides in Practice of Silviculture textbook.

1960s Using phenoxy herbicides for preparing sites and selectively controlling vegetation is common practice

1960s Amitrole and the organic arsenicals (MSMA, cacodylic acid) used

1960s and 70s - picloram, dalapon and the triazine herbicides introduced

Late 1970s and 80s - glyphosate (Roundup®) and triclopyr (Garlon®) introduced. Phenoxy herbicides begin to be replaced due to greater efficacy and the controversy around 2,4,5-T

Late 1980s and 90s - imazapyr (Arsenal®) and the sulfonylurea herbicides (Oust® and Escort®) introduced

References

Agrios, G. N. 1988. Plant Pathology, Third Edition. Academic Press, Inc., San Diego, California.

Delaplane. K. S. 2000. Pesticide Usage in the United States: History, Benefits, Risks, and Trends. Cooperative Extension Service. The University of Georgia, College of Agricultural and Environmental Sciences. Bulletin 1121/Reprinted November, 2000. http://pubs.caes.uga.edu/caespubs/pubs/PDF/B1121.pdf

Gianessi, L.P. and S. Sankula. 2003. The value of herbicides in U.S. crop production. National Center for Food and Agricultural Policy. www.ncfap.org

Hawley, R. C. 1929. The practice of silviculture: with particular reference to its application in the United States of America. Second edition. John Wiley, New York, New York, USA.

Janick, J. 2004. History of Horticulture. Department of Horticulture and Landscape Architecture. Purdue University, USA. www.hort.purdue.edu/newcrop/history/

Smith, A.E. and D. M. Secoy. 1975. Forerunners of Pesticides in Classical Greece and Rome. Agricultural and Food Chemistry, Vol. 23, No. 6, Page 1050. www.hort.purdue.edu/newcrop/history/lecture18/r_18-1.html

Smith, A.E. and D. M. Secoy. 1976. A Compendium of Inorganic Substances Used in European Pest Control before 1850. Agricultural and Food Chemistry, Vol. 24. No. 6, Page 1180. www.hort.purdue.edu/newcrop/history/lecture31/r_31-1.html

Smith R.F. and R. van den Bosch. 1967. Integrated Control in Pest Control Biological, Physical and Selected Chemical Methods. Kilgore, W.W. and R.L. Doutt (eds.) Academic Press, New York. P295-340.

Tvedten, S. L. 2002. The Best Control. Get Set Inc., 2530 Hayes St. Marne, MI 49435-9751, US.

Van Driesh, R.G.V., and T.S. Bellows. 1996. Biology and Arthropod Parasitoids and Predators. Pp. 309-335. *In* Biological Control. Chapman and Hall, International Thompson Publishing, NY.

Wagner, R. G., M. Newton, E.C. Cole, J. H. Miller, and B. D. Shiver. 2004. The role of herbicides for enhancing forest productivity and conserving land for biodiversity in North America. Wildlife Society Bulletin, 32(4):1028–1041

This publication was funded through a grant by the Renewable Resources Extension Act in cooperation with Louisiana Tech University, School of Forestry.

This publication is also part of a regional peer reviewed Extension Service publication series. Editor, William G. Hubbard, Southern Regional Extension Forester, 4-402 Forest Resources Building, The University of Georgia, Athens, GA 30602. Please visit www.sref.info for more information.