A History of Crop Protection and Pest Control in our Society

Since the dawn of time mankind has had two primary goals - obtaining enough food to survive and improving the quality of life. The single most important task facing a society is the production of food to feed its population. A country or society has to feed its people before it can devote resources to education, arts, technology or recreation. In some areas of the world this remains the primary focus of the entire population…producing or accessing food to feed its people. In these countries food can account for over 60% of annual income needs. Other societies, like ours, are more fortunate as we have made tremendous strides in the area of food production - to the point where a healthy diet only requires an average 11% of our annual incomes.

Today, only 2% of our population is involved in primary agriculture, producing enough food for not only our population, but for others around the world. A basic reason for our ability to increase our productivity is our ability to control pests - weeds, insects, and diseases using crop protection products.

Many in our society feel we have only been using pesticides over the last few decades. In fact, mankind has a history of using crop protection products in the production of our food supply and protection of our environment. Throughout history we have seen the evolution of pest control products from non-selective, naturally occurring compounds to highly specific synthetic and biological materials that control only specific pests.

Herbicides

Chemicals such as common salt have been used for centuries for weed control. The era of chemical weed control is generally recognized as starting in 1896. Bonnet in France found that Bordeaux mixture used in vines to control powdery mildew also provided control of specific weeds. In the first half of the twentieth century, overtly toxic compounds such as sodium arsenate and sulfuric acid were used at rates of several kilograms per hectare. As the century moved forward, safer and more selective herbicides were developed and introduced for specific crops and use patterns. Today, we see the registration of low use rate herbicides (applied at grams per hectare) that interact with specific biochemical sites to produce selective and environmentally safer weed control. Herbicide tolerant crops are also being grown that allow producers to achieve broad-spectrum weed control while not harming their growing crop.

Insecticides

Early insecticides were primarily naturally available substances that were used because they controlled the pest without harm to the crop or humans being protected. The real expansion in the discovery and registration of insecticides occurred during and after the Second World War. This period represented a pivotal point in the overall history of pesticides. The latter half of the twentieth century has produced more selective insecticides with reduced impact on the environment, applicators and beneficial insects. As well, biological control tools including the use of predacious insects and genetically engineered crops, like corn resistant to corn borer, has advanced this area of pesticide use.

Fungicides

As with herbicides and insecticides, naturally occurring compounds predominated until the 1800's when sulphur, followed by formulated copper compounds, gained prominence as effective disease control tools. In the 1960's and 1970's several highly effective protectant fungicides were developed and registered to revolutionize disease control. This was followed by the introduction in the final decades of the century by the introduction of low rate systemic fungicides that were very specific in terms of the mode of activity and diseases controlled.

A History of Crop Protection and Pest Control Product Use

Product and Use Patterns of Chemicals

A summary of crop protection and pest control use patterns over time and the mention of specific product highlights are on the following pages.

Overview of early use patterns

Most pest control products were naturally occurring and basic poisons. They were non-selective in nature, persistent and toxic to many forms of life. Insecticides included arsenic, lead and fluoride. Herbicides included ashes, salts, and smelter sludges. Fungicides included chalk, woodash and sulphur.

1200 BC

- The first recorded use of non-selective herbicides as Biblical armies used salt and ash on the fields of the conquered.

1000 BC

- Homer refers to sulphur used in fumigation.

100 BC

- The Romans use hellebore to control rats, mice and insects.

25 BC

- Virgil reports seed treatments using “niter and amurca”.

900

- Chinese use arsenic to control garden insects.

1300

- Marco Polo writes about the use of mineral oil against mange on camels.

1649

- Rotenone used to paralyze fish in South America.

1669

- First mentions of the use of arsenic in Western societies, used with honey in ant bait.

1690

- Tobacco extracts used as contact insecticides.

1787

- Soap mentioned in publications for use as an insecticide.

Overview of the 1800's

Insecticides included botanicals, nicotine, rotenone and pyrethrums. These products were more specific in terms of control, but not very stable for use in agriculture given rapid breakdown in the environment. It was the century where disease control using sulfur and copper compounds became common on fruits, vegetables and ornamental plants. Herbicides included Bordeaux mixture and Hydrogen sulfide. Both industrial and nourishment goals drove the search for new and better pesticides. With fungicides, the threat of famine and the need to control diseases under industrial settings such as wooden railroad ties to keep them from rotting, led to several new product introductions.

1800

- Spray of lime and sulfur recommended in insect control.
- Whale oil used as a scalecide.

1810

- Arsenic dip recommended for sheep scab control.

1820's

- Sulphur recommended as a fungicide for mildew control in England.

1840's

- Phosphorus paste declared an official rodenticide in Prussia, also used as a cockroach control.
- Rotenone derived from the roots of the derris plant used as insect control in Asia.

1850's

- Pyrethrum from the flower heads of a species of chrysanthemum first used in the United States.

1860's

- Mercuric chloride solutions used as fumigant to control soil borne pests.

1870's

- Kerosene emulsions used as dormant sprays on deciduous trees.
- Hydrogen cyanide first used as a fumigant by museums.

1880's

- Lime sulphur used in California against San Jose Scale.
- Millardet discovers the value of Bordeaux mixture in France.
- Hydrogen cyanide used for citrus tree fumigation in California.
- Lead arsenate first prepared and used to control gypsy moth in Massachusetts.

1890's

- Copper sulfate first used to kill weeds in grain fields.
- Oil of citronella used as a mosquito repellent.
- Formaldehyde introduced as a fumigant.

Early 1900's to
Post - WWII War Period Overview

Many pesticides were the by-products of coal gas production or other industrial processes. Early organics, nitrophenols, chlorophenols, creosote, naphthalene and petroleum oils were used for insect and pest control. Most of the products used were non-selective and toxic to both users and non-target organisms. Many of these products were developed as a result of the overuse of arsenate based compounds used extensively in the United States on fruits, vegetables and cotton with the result being the build-up of harmful residues. Herbicides for the era included ammonium sulfate and sodium arsenate.

The modern era of synthetic organic pesticides began in the 1930's. The research behind medical (including antibiotics) and military uses funded research that led to the discovery of many pesticide families that are still in use today. A real breakthrough in weed control occurred with the introduction of 2,4-D in the 1940's for broad-spectrum broadleaf weed control in corn and cereal crops.

The early twentieth century brought the introduction of organomercurials for disease control and organochlorines such as DDT for insect control. These products were very persistent and efficacious with good properties for agriculture and for public health (such as DDT for the control of malaria carrying mosquitoes and the control of louse-borne typhus), but not desirable after control was achieved. The introduction of organophosphates brought a new class of insecticides with reduced persistence and lower risks to both users and the environment.

Another key innovation during this period was the manufacture and refinement of equipment for effectively applying these materials to crops and plants.

1900's

- Value of lime sulphur to control apple scab discovered in New York.
- Calcium arsenate used as an experimental insecticide.

1910's

- Derris given patents as an insecticide in Britain.
- Zinc arsenate first recommended as an insecticide.
- Organomercurials first used as seed treatments to control seedling diseases.

1920's

- Airplanes first used to apply insecticide dusts in Ohio.
- Selenium compounds tested as insecticides.
- Arsenic tolerance levels established on apples by FDA in U.S.
- Alkyl phthalates patented as insect repellents.
- Cryolite introduced as an insecticide.

1930's

- First fixed nicotine compound used as an insect stomach poison.
- Methyl bromide first used in France as fumigant.
- Pentachlorophenol introduced as a wood preservative to act against fungi and termites.
- *Bacillus thuringiensis* first used as microbial insecticide.
- DDT discovered to be insecticidal in Switzerland.

1940's

- Introduction of 2,4-D, the first growth regulating herbicide.
- First dithiocarbamate fungicide zineb registered for use.
- Chlordane introduced.
- Introduction of first organophosphate insecticides including parathion. That had the advantage of rapidly degrading to non-toxic compounds in the environment.
- Introduction of chlorinated hydrocarbon products such as aldrin and dieldrin.
- First appearance of the dicarboximide fungicide captan.

1950's to 1970's Overview

The post-war period saw the rapid introduction of a range of new pest control tools including many core insecticides and fungicides still in use today. The evolution of materials continued with new chemical families discovered that offered reduced persistence and environmental concerns along with attractive and valued benefits to producers and end-users.

This period saw the introduction of soil residual herbicides such as the triazine herbicide atrazine evolving to the introduction of non-residual products like glyphosate in the 1970's. Several broad-spectrum fungicide families with active ingredients like chlorothalonil were introduced followed by the introduction of highly selective systemic fungicides that worked on specific metabolic processes in specific diseases. It was also the period of introduction for synthetic pyrethroid insecticides. The discovery and use of systemic and single mode of activity pesticides also created resistance concerns and the introduction of resistance management strategies to keep these products viable tools for producers.

The evolution of scientific procedures for evaluating the impact of pesticides on users and the environment along with the introduction of newer classes of reduced risk products led to the removal of many older classes of chemistries that were persistent with negative impacts on the environment.

1950's

- Registration of the organophosphate insecticide malathion
- Introduction of maneb fungicide.
- Introduction of carbamate insecticides.
- First use of streptomycin for fungal and bacterial disease control.
- Diazinon discovered in Germany.
- Deet introduced as insect repellent.
- Introduction of first carbamate insecticide carbaryl.
- First broad-spectrum and soil residual triazine herbicide, atrazine
- First bypyridylium herbicide, paraquat, introduced which provided fast activity and desiccation properties.

1960's

- Bacillus thuringiensis (Bt) first registered for use on lettuce and cole crops. Treflan (trifluralin) introduced to market as a broad-spectrum grass and broadleaf soil applied herbicide from dinitroaniline family .
- Introduction of mancozeb broad-spectrum fungicide.
- First soil applied insecticide aldcarb introduced.
- First systemic fungicide introduced with carboxin. Introduction of methomyl insecticide.
- Introduction of second systemic fungicide family with benomyl registered.
- Discovery of first family of synthetic pyrethroids, showing greater activity and selectivity when compared to naturally occurring pyrethrums.

1970's

- Introduction of pre-plant herbicides like triallate to control wild oats in cereal crops.
- Glyphosate herbicide introduced.
- Development of first photo-stable synthetic pyrethroids, permethrin. Natural pyrethrums had the disadvantage of breaking down rapidly in sunlight.
- Cancellation of virtually all non medical DDT uses.
- First standards introduced in North America for worker re-entry into treated areas.
- Cancellation of aldrin and dieldrin use patterns.
- Introduction of Ficam. Most use patterns for mercury based compounds cancelled.
- Introduction of bentazon for post-emergent broadleaf weed control in soybeans and corn.
- Introduction of benzamide class herbicide alachlor for pre-emergent weed control in corn and soybeans.
- First registration of a pheromone for use on cotton to manage pink bollworm in the US.

Overview from the 1980's to Present Day

The close of the twentieth century brought the evolution to newer classes of highly specific, low toxicity and low use rate, insecticides and fungicides. These products were used at the rates of millilitres or grams per hectare. Insecticides were registered that controlled only certain stages of the lifecycle without harming beneficial species in crops like apples. Likewise fungicides were introduced that featured both forward and backward systemic activity to control diseases like apple scab in apples. This period also saw the refinement of mature products in terms of use patterns with the introduction of newer and more user-friendly and environmentally safe formulations.

As well, we entered into an era of genetically engineered pesticides and crops designed or bred to reduce or eliminate the use of pesticides in controlling specific pests. Examples include corn borer resistant corn or canola resistant to diseases like blackleg. The use of pheromones to disrupt insect mating habits and the use of microorganisms to combat diseases were also introduced and used on a broader scale in specific crops like greenhouse vegetables, or fruit crops like apples.

The latter half of the 1990's saw the introduction of herbicide tolerant crops including soybeans, corn, canola and cotton using both traditional and transgenic breeding techniques, and the introduction of varieties of corn and cotton resistant to corn borer and boll weevil respectively. These introductions revolutionized pest control and dramatically reduced the volumes of pesticides used on these crops by either eliminating the need or switching use patterns to more environmentally friendly or broad-spectrum products like glyphosate or glufosinate-ammonium.

1980's

- Introduction of bromoxynil for post-emergent broadleaf control in cereals and corn.
- Introduction of dicamba for post-emergent broadleaf weed control in cereals and corn.
- Introduction of metribuzin for pre-emergent weed control in soybeans and pulse crops.
- Introduction of post-emergent herbicide diclofop-methyl to control grassy weeds including wild oats in cereal crops. This introduction helped to revolutionize weed allowing post-emergent applications and direct seeding.
- Introduction of metalaxyl systemic fungicide to control late blight in potatoes.
- Introduction of clofentazine miticide to control larvae of selected mite species in apples.
- Introduction of first Group 2 ALS/AHAS inhibitor herbicide.
- Introduction of metolachlor herbicide for pre-emergent weed control in soybeans and corn.
- Removal of alachlor from Canadian market.
- Controversial removal of daminozide from the apple market based on a 60 Minutes story that ignored research that stated it would take the consumption of dozens of apples per day for an entire lifetime to have a one in million chance of developing cancer.

1990's and 2000 (Canada)

- Widespread introduction of low use rate Group 2 ALS/AHAS inhibitor class of chemistry. Some examples include imizathepyr herbicide for soybeans and pulse crops; nicosulfuron for post-emergent quackgrass control in corn; metsulfuron-methyl and tribenuron methyl for control of broadleaf weeds in cereals.

- Introduction of several low use rate Group 1 (ACCase control) and Group 2 (ALS/AHAS inhibitors) graminicides including fenoxaprop-ethyl, tralkoxydim and later clidinafop-propargyl for wild oat and annual grass control in cereal crops.

- Development of herbicide resistance management strategies and education programs for growers and industry on herbicide classes and modes of action to manage herbicide resistance concerns with in particular Group 1 and 2 herbicides in cereal crops and soybeans.

- Introduction of low use rate sterol inhibitor fungicides including myclobutanil and later flusilazole which provided both protectant and kick-back or eradicant disease control for apples and grapes.

- Adoption of intensive IPM programs and practices in fruit., vegetable, and greenhouse crops.

- Introduction of clopyralid for thistle and broadleaf control in cereals and corn.

- Introduction of glufosinate ammonium, a broad-spectrum non-selective herbicide based on a soil bacterium.

- Introduction of low use rate insecticide imidacloprid for control of Colarado potato beetles, which had a major positive impact on reducing insecticide useage in many potato production areas.

- Introduction and rapid adoption of herbicide tolerant varieties for Roundup Ready (glyphosate), Liberty Link (glufosinate) and Smart (imizathepyr and related chemistries) in canola. The introduction of these technologies reduced herbicide use by several thousand tonnes over a 4 year period.

- Introduction of herbicide tolerant hybrids in corn for similar herbicide systems.

- Introduction and rapid adoption of Bt corn resistant to European corn borer and stacked hybrids featuring insect and herbicide tolerance.

- Introduction of *stewardshipFirst* program by CropLife Canada to foster stewardship of crop protection product lifecycles and protection of our population and the environment.

- Introduction of new generation systemic fungicides to control late blight in potatoes including propamacarb, dimethomorph, cymoxanil.

- Introduction of first strobilurin class of broad-spectrum and systemic fungicides, based on naturally occurring fungicides, for use on apples and potatoes.

An Evolution of Safety

Research over time has led to the continuing discovery of new pest control products that offer both improved environmental profiles and improved safety to consumers, homeowners and applicators. Research in the latter half of the twentieth and into the twenty-first century in particular has focused on the discovery and commercialization of products that provide a much higher level of safety to both users and the environment. These products are much more specific and less broad-spectrum in nature, targeting specific pests or pest families and using greatly reduced use rates.

Insecticides	**Oral LD_{50}(mg ai/kg)* (Mammalian)**	**Discovery/Registration**
Nicotine	50-60	1690
Rotenone	132-1500	1840's
Paris Green	22	1880's
Lead arsonate	150	1890's
DDT	113	1930's
Carbaryl (Sevin)	246-283	1950's
Chlorpyrifos (Dursban)	96-270	1970's
Cypermethrin(Cymbush)	250	1970's
Imadacloprid(Admire/Merit)	450	1990's
Indoxacarb (Avaunt)	687-1867	2000
Fungicides		
Lime sulphur	400-500	1800
Copper sulphate	472	1880's
Mercuric Chloride	37-100	1860's
Pentachlorophenol	50-500	1930's
Captan	9,000	1940's
Benomyl (Benlate)	>10,000	1960's
Mancozeb (Dithane)	11200	1960's
Chlorothalonil(Bravo)	>10,000	1970's
Vinclozolin (Ronilan)	>16,000	1990's
Herbicides		
Arsenic acid	48-100	1900/1920's
Copper Sulphate	472	1890's
2,4-D amine	1492	1940's
Atrazine	1600	1950's
Glyphosate (Roundup)	>5000	1970's
Fenoxaprop-ethyl (Excel)	2565	1980's
Imazethepyr(Pursuit)	>5000	1980's
Nicosulfuron(Accent)	>5000	1990's

**The relative toxicity of a pesticide can be measured by its LD_{50}. This is the amount of the active ingredient (ai) of the chemical in milligrams used per kilogram of test animal (usually rats) that kills 50% of the test animals, with a single high dose.*