Agricultural Pesticides and the Environment

March-2017

Outlines

- Definitions
- History of Pesticide use
- Classes of Pesticides
- Pesticides application and handling
- Environmental effects

Introduction

- Agriculture?
- Crop/Plant?
- Protection?
- Crop/ Plant Protection?
- Pest?
- Agrochemicals?
- Agricultural Pesticides?

Introduction

Agriculture:

- the production of food, feed, fiber and other goods by the systematic growing/harvesting of plants, animals and other life forms.

Crop

- A crop is any plant that is grown in significant quantities to be harvested as food, livestock fodder, or for any other economic purpose (food crops, fodder, cash crops)

Protection

refers to anything that helps ward off some threat; the preservation from injury or harm.

Introduction

Crop Protection

- The entire range of measures to prevent or minimize damage and yield reduction of useful plants (e.g. crops) by using all relevant scientific knowledge in an ecological and economically suitable ways.

Pest

- Any organism that interferes with the activities and desires of humans and include: pathogens, weeds, nematodes, mollusks, arthropods , vertebrates

pests are all organisms within the cropping environment that cause injury to the crop and are capable of reducing yield and/or quality

Introduction

"Pesticides are one method of pest management.

- Used properly, they pose little potential damage to humans or the environment.

- Used improperly they can cause significant damage."

Definition - Simple

The function of a pesticide is to kill or harm some form of life.

Definition - EPA

"…a pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest."

"…a pest is any harmful, destructive, or troublesome animal, plant or microorganism."

US Environmental Protection Agency (EPA)

Definition - FIFRA

"… any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any insects, rodents, nematodes, fungi, or weeds or any other form of life declared to be pests. … and any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant."

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA – 1947)

“PLANT/CROP PROTECTION” PESTICIDE USE

Some Definitions

Pesticide = a substance that kills a pest (insect, weed, bacteria, nematode…)

1. Herbicide = plant killer
2. Insecticide = insect killer
3. Rodenticide = rodent killer

- Other "cides"??

Pesticide type	Organism (s) affected
Fungicide	Fungi
Bactericide	Bacteria
Herbicides	Plants (weeds)
Silvicides	Trees
Algaecides	Algae
Nematicides	Nematodes
Molluscicide	Slugs and Snails
Insecticides	Insects
Adulticide	Adults
Larvaecide	Larva
Ovicide	Eggs
Aphicide	Aphids
Acaricide	Spiders
Miticide	Spider mites
Perdacide	Vertebrates
Rodenticide	Rodents
Avicide	Birds
Piscicide	Fish

Historical Records of pesticide use

The use of pesticide has an old history. The following is a summery of pesticide development.

Earlier periods (before 1940s)

The earliest chemicals used for pest control were inorganic chemicals:

- Sulfur is used for fumigating houses in 1000 B.C. E.
- Arsenic has been introduced for insect control since 900 C.E in China
- 1880 Copper and lime mixtures were introduced for the control of Downy mildew in grape
- Borax was introduced as insecticide and herbicide since the late nineteenth century.
- Chlorates were introduced early in the twentieth century for non selective weed control

Historical Records of pesticide use

The Era of Optimism (1942-19620)

The second phase, synthetic organic chemicals (1940s-1970s)

- They were introduced late in the nineteen century.
- Most of them were discovered as petroleum by products.
- During second world war and then after the discovery of many these types of pesticides has increased (1940s)
- The most notable one is the discovery of DDT rapidly followed by the discovery of **Phenoxy compounds** with selective herbicidal properties- was embraced as a single tactic chemical control of pest- set as **silver bullet** approach.

- The development of synthetic organic pesticides rapidly increased during 1950s and 1960s. Pesticide played a major role in increasing food production.

Historical Records of pesticide use

The Era of Optimism (1942-19620)

The second phase, synthetic organic chemicals (1940s-1970s)

- People started to question the reliance on chemicals.
- The publication of **Silent Spring** by Rachel Carson (1962) probably highlighted problems and potential environmental impacts of widespread pesticide use

- **1960-1980**, the development of sensitive tools for analytical chemistry exerted a strong influence on pesticide use and regulation. People have started to determine pesticide level in food and environment.

- Re-evaluation of the role of pesticide in agriculture and to their utility in pest management programs

Historical Records of pesticide use

The era of doubt (1962-1976)

The era of optimism led to the mis-use of pesticides. Pesticides were used carelessly-

- created hazards for non-target organisms
- resulted in the technological contamination of the environment.
- As the result of this:

  i) the number of pest species showing resistance to one or more pesticides increased dramatically.

  ii) the cost of pesticides has increased dramatically

  iii) In spite of heavy pesticide use, the wide occurrence of pest outbreak recorded

  iv) there wide spread contamination of food webs and general ecological toxicity

Historical Records of pesticide use

Suspicion and doubt about pesticides set its root in the minds of people and scientists

- In the mean time, a lucid description of the real and potential damages of mis-use of pesticide was published in a book called **Silent Spring**, Rachel Carson (1962).
- This book stimulated research on non-chemical methods of pest control and more selective pesticides.
- The combined effect of all of the above events together with the exponentially rise of the cost of pesticides provided the necessary feed back for limiting the use of chemical control and led to the development of the concept of IPM.

Historical Records of pesticide use

The era of IPM and organic farming (1976 on wards)

- The root of IPM was before 1940s. Stren *et. al* (1959) systematised the integration of chemical and biological methods of pest control,
- The concept of IPM became real at the XV international congress of Entomology in 1976.
- **It is a shift in thinking.** The concept does not exclude the use of pesticides

Historical Records of pesticide use - Summary

- **Earlier periods (before 1940s)-The earliest chemicals used for pest control were inorganic chemicals**
- **The Era of Optimism (1942-19620 -the second phase, synthetic organic chemicals (1940s-1970s)**
- **The era of doubt (1962-1976)-The era of optimism led to the mis-use of pesticides**
- **The era of IPM and organic farming (1976 on wards**)

Classes Of Pesticides

Pesticides can be classified considering their origin but are commonly classified in several ways:

- Target organism or even devt stage
- Mode of action
- Application timing or usage
- Chemical class — Increasingly diverse

Classes Of Pesticides

- **Insecticides (kill insects)**
  - **Organochlorines**
  - **Organophosphates**
  - **Carbamates**
  - **Synthetic Pyrethroids**
- **Herbicides (kill plants)**
- **Rodenticides (kill rodents)**
- **Fungicides (kill fungus)**
- **Fumigants (kill whatever)**

Insecticides

- **Insecticides (kill insects)**
  - **Organochlorines**
  - **Organophosphates**
  - **Carbamates**
  - **Synthetic Pyrethroids**

Organochlorines

Examples

DDT, methoxychlor, aldrin, dieldrin, endrin, heptachlor, kepone, lindane, chlordane

Toxicity

Acute toxicity variable, CNS – convulsions, coma

Environmental characteristics

Highly persistent in environment, fat soluble, bioaccumulation, biomagnification

Mostly banned in US and Europe

Organophosphates-1

Examples

Malathion, parathion, guthion, diazinon, TPN, TOCP, nerve gases – tabun, sarin, soman, VX

Toxicity

Acute toxicity highly variable – Parathion, TPN, sarin very toxic, malathion much less

Environmental characteristics

Rapidly degrade in outdoor environment (last longer in doors), do not bioaccumulate

Organophosphates-2

Mechanism of toxicity

Inhibition of acetylcholinesterase (AchE) in nerve tissue

Symptoms

Over-stimulation of parasympathetic nervous system --- salivation, constricted pupils, diarrhea, sweating, muscle twitching, etc – coma and death

Treatment

Reverse AchE inhibition effects – use Atropine to block Ach receptors or AchE inhibiton with 2-PAM

Carbamates

Examples

Sevin (carbaryl), Baygon (propoxur), Temik (aldicarb)

Toxicity

Aldicarb very toxic, others less toxic

Mechanism and signs of toxicity

Similar to organophosphates

Environmental characteristics

Not persistent in environment

Pyrethroids

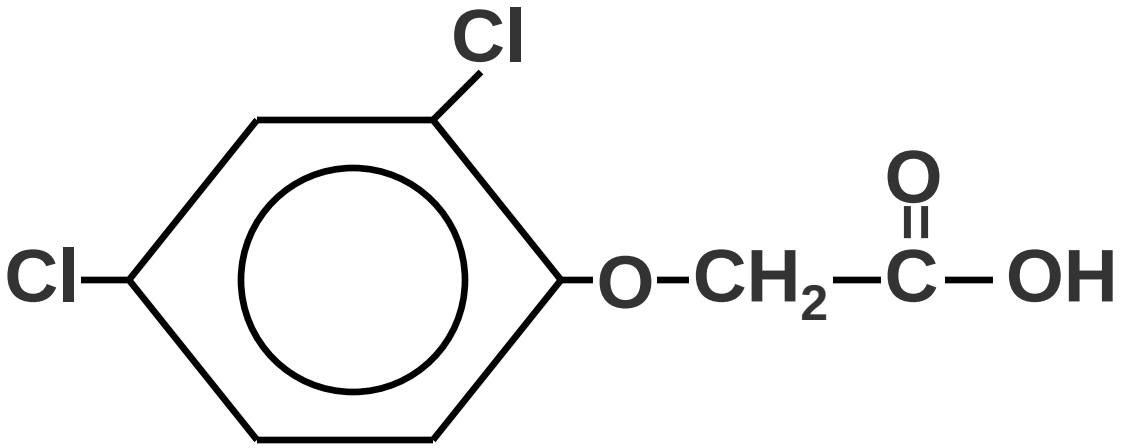
Synthetic Pyrethroids

- Based on naturally occurring pyrethrums – from chrysanthemum flowers
- Discovered by Chinese in 100 AD
- First commercial use in 1800's
- First synthetic pyrethroids in 1980
- Relatively low animal toxicity
- Effects movement of cellular Na^+ (sodium)
- Use Growing rapidly

Herbicides (Kill Plants)

- **Silvex, 2,4-D, D,4,5-T**
  - Most widely used
  - Possible carcinogen
- **Paraquat & diquat**
  - Serious toxicity following accumulation in lungs –

Herbicides 2,4-D



One of the most widely used herbicides

Rodenticides (kill rodents)

- **Botanicals**
  - Red squill – effects heart
  - Strychnine – blocks glycine receptors in spinal cord - convulsions
- **Inorganics**
  - Phosphorous – GI track
  - Thallium – hair loss, nervous system
  - Zinc phosphide – GI track
- **Anticoagulants**
  - Warfarin – inhibits blood clotting
  - Vacor – newer blood clot inhibitors

Origins of Pesticides

Three origins of pesticides are recognized

- Inorganic chemicals: derived from chemical elements other than carbon
- Synthetic organic chemicals: carbon-containing compounds typically synthesized and derived from petroleum-based chemicals
- Biopesticides: biological origin (products of organisms such as antibiotics or organisms themselves such as bacterial suspensions)

Mode of Action of pesticides-Examples

- **Broad Spectrum** -- Kills broad range of pests
- **Contact Poison** -- Kills by contacting pest
- **Disinfectant (Eradicant**) -- Effective against pathogen that has already infected the crop
- **Germination Inhibitor** -- Inhibits germination of weed seeds, fungus spores, bacterial spores.
- **Nonselective** -- Kills broad range of pests and/or crop plants, usually used in reference to herbicides
- **Nerve Poison** -- Interferes with nervous system function
- **Protectants** -- Protects crop if applied before pathogens infect the crop
- **Repellents** -- Repels pest from crop or interferes with pest's ability to locate crop
- **Systemic** -- Absorbed and translocated throughout the plant to provide protection
- **Stomach Poison** -- Kills after ingestion by an animal

Mode of Action of pesticides-Examples

- **Anti-coagulant** – decrease ability of blood to form clot
- **Juvenile Hormones** – IGR regulate the growth and molting process of insects
- **Acute Muscle Poisons** – Alkaloids inducing acute muscles poisons
- **Contraceptive** -- Inhibits reproduction
- **Antifeedants** – Metaldehyde causing pest to stop feeding

Mode of Action of pesticides-Herbicides

- **Photosynthesis inhibitors**– mode of action of several families of herbicides (triazine), only toxic to green plants
- **Tubilin Inhibitors** – Tubilin is a component of microtubules involved in cell division-TI leads to abnormal cell wall production and cessation of cell division
- **Inhibition of Aminoacid biosynthesis** – block the action of enzymes involved in synthesis of AA essential in plants
- **Nuclear regulation** – herbicides in the phenoxy group regulates the transcription of DNA-encoded information to RNA and thus modify plant growth
- **Safeners** – Not phytotoxic, but when added to herbicides to make them less toxic to a non-target plant

Classification by Timing/Usage

Annual Crops

- **Seed Treatment** -- Pesticide coats or is absorbed into the seed.
- **Pre-Plant** -- Pesticide applied any time before planting
- **At-Planting** -- Pesticide applied during the planting operation
- **In-Furrow** -- In the planting row, direct contact with crop seed
- **Side-Dress** -- Next to the row, no direct contact with crop seed
- **Broadcast** -- Distributed over the soil surface.
- **Pre-Emergent** -- Before the crop has emerged from the ground
- **Post-Emergent** -- After the crop has emerged from the ground
- **Dormant** -- Applied during winter dormancy
- **Bud Break** -- Applied as dormancy is broken
- **Pre-Harvest** -- Just before crop is harvested
- **Post-Harvest** -- After crop is harvested

The Selectivity Concept

- Key concept in pesticide usage in IPM
- Pesticides often classified as "selective" or

"non-selective"

- Meaning of these terms in common usage is context-dependent (weeds vs. insects)
- More formally, there are two types of selectivity – Physiological and Ecological

Physiological Selectivity

- Relative toxicity of pesticides under controlled application conditions
- Species-specific susceptibility to a pesticide.
- Measured as a ratio of LD50's of non-target/target species
- Assumes all individuals & species equally treated.

Ecological Selectivity

- Differential mortality based on pesticide use
  - Formulation (e.g. granules result in more mortality on soil pests than on foliar NE's)
  - Placement (e.g. spot sprays, seed treatments, in-furrow).
  - Timing (e.g. pre vs. post-emergent applications, diurnal timing for bees)
  - Dosage – Reduced dosage usually used in conjunction with one of those above

USING PESTICIDES SAFELY

- Plant selection?
- Identify pest
- Read the label
- Wear protective clothing
- Use organic pesticides
- Accept some damage

Pesticide Routes of Entry

- Dermal (skin) most common
- Oral (swallowed)
- Respiratory (breathed)
- Ocular (in the eyes)

LABEL DIRECTIONS

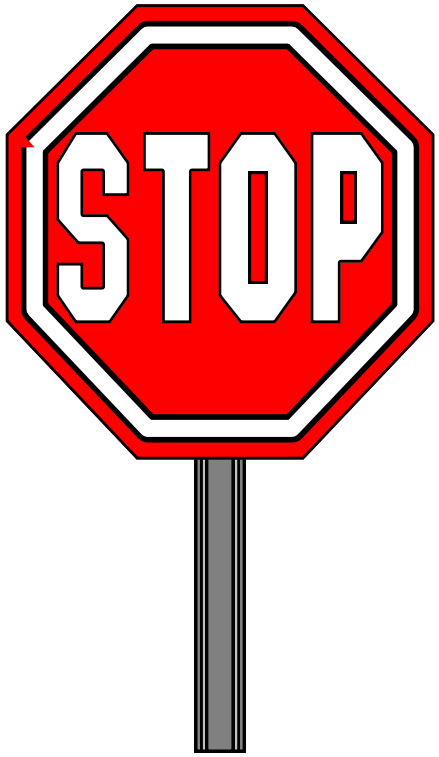
- Product and brand identification
- Active ingredients
- Precautionary statements
- First aid instructions
- Note to physicians
- Directions for use
- Storage and disposal

SIGNAL WORDS

- Caution (C)
- Warning (W)
- Danger (D)
- Restricted (R)

PROTECTIVE CLOTHING

- Plastic goggles
- Filter mask
- Long sleeve shirt
- Long pants
- Rubber gloves
- Boots



PLANT SELECTION

- Insect and disease resistance
- Site selection
- Visit nurseries or garden centers
- Review catalogs and other publications
- Check with Extension

IDENTIFY THE PEST

- Insect damage
- Disease damage
- Weed damage
- Cultural damage

STORAGE AND DISPOSAL OF PESTICIDES

- Store in original containers
- Out of the reach of children
- Mix what is needed - use what is mixed
- Clean up spills
- Container disposal
- Pesticide disposal

EMERGENCY PROCEDURES

- "If you suspect someone has been poisoned by a pesticide immediately:"
  - Follow label instructions
  - Call a doctor or take the person to a hospital
  - Call the emergency
- If a pesticide is spilled on a person
- If a pesticide is spilled in an enclosed space

AGRICULTURAL CHEMICALS MANUAL

This is the bible which Master Gardeners must follow when providing advice to the gardening public.

“Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label.”

AGRICULTURAL CHEMICALS MANUAL

- General information
- Safety
- Application
- Specimen preparation/identification
- Control

AGRICULTURAL CHEMICALS MANUAL

- Insect and disease control
- Chemical weed control
- Plant growth regulators
- Fertilizer use
- Animal damage control

Why are pesticides used in agriculture and the environment?

1. In Agriculture:

a. Use of "crop protecting" agents improves yield and quality of agricultural products, consumer preferences

b. Prevents the spread of diseases to crops and livestock (Pierce's Disease)

c. The use of pesticides in Agriculture and Forestry is regulated by the Ministry of Agriculture

Why are pesticides used in agriculture, society and the environment?...continued

2. **Society & Environment:**

   a. Aesthetics - used regularly in city parks and other recreational areas to control insect damage and weeds (ie Parks, ball parks, schools, etc)

   b. Protect humans from insect-borne diseases, mosquitoes transmit many diseases

   c. Protect our food supply. In developing countries (India), up to 1/3 of all harvested grain is destroyed by rodents and insects.

Concerns With Pesticide Use

1. **Environmental concerns**

   a. They kill beneficial insects and plants (non selective).

   b. Pollution – runoff of herbicides and insecticides into irrigation water and then into rivers - damages wildlife habitat, kills fish.

   c. Cause cancer – organophosphates

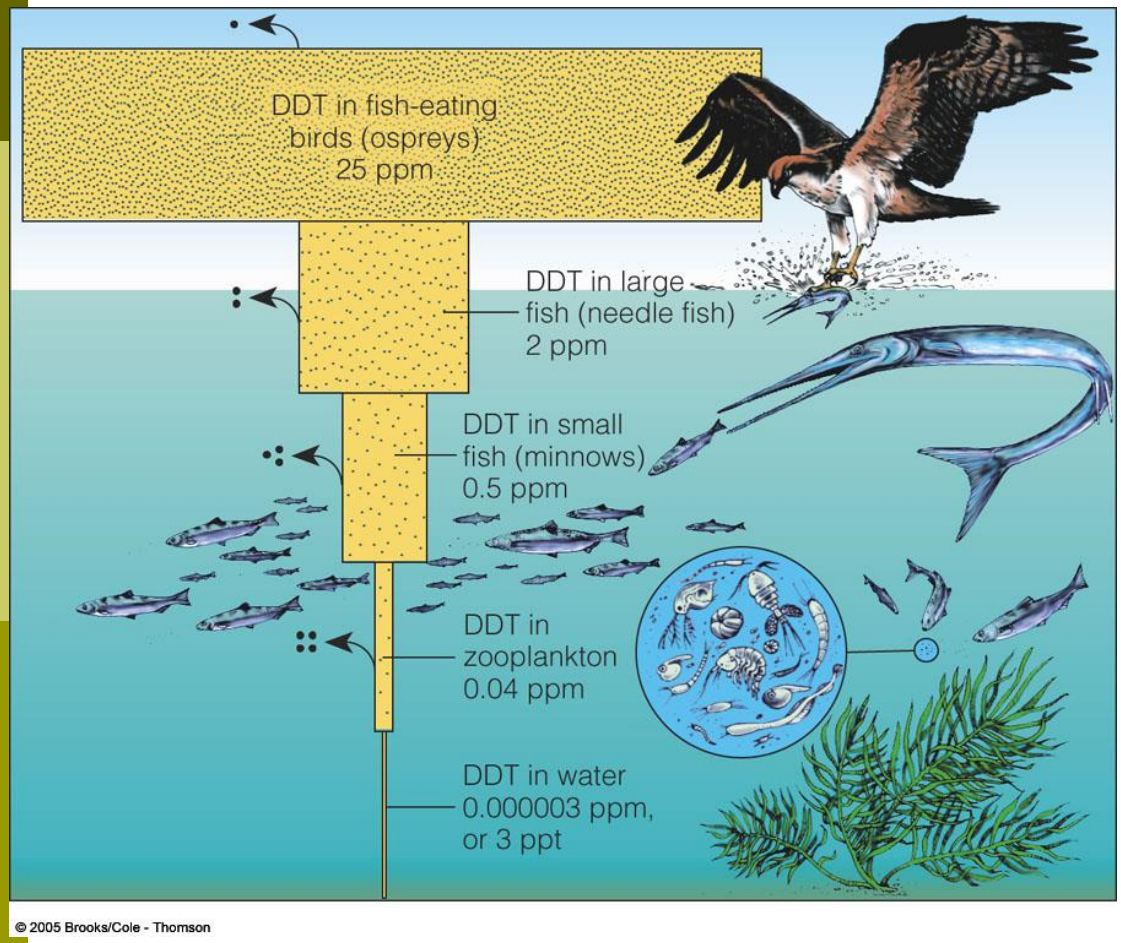
   d. Disrupt the natural ecosystem and natural biodiversity

   e. Creates chemical resistance – insects and weeds. Examples?

“Bio-magnification”

- Biomagnification, also known as bioamplification or biological magnification , is the increase in concentration of a substance, such as the pesticide DDT, that occurs in a food chain as a consequence of:
- Persistence (can't be broken down by environmental processes)
- Food chain energetics
- Low (or nonexistent) rate of internal degradation/excretion of the substance (often due to water-insolubility)

Bioaccumulation and Biomagnification



- Persistent (non-biodegradable) toxins build up in an animal over time = **bioaccumulation**
- Become more concentrated at higher trophic levels = **biomagnification**

"Bio-magnification"

- *Duration*…Chlorodane – killed lots of bugs, 30 year half-life, very stable in soil. Improper application of insecticide caused it to be banned.
- *Accumulation*…DDT – stays in the environment, organisms pick up the molecules and it stays in the animal's tissues…animals eat animals and it passes on…Raptor egg shell thickness
- *Resistance* develops – kill 99%; 1% left that are resistant. Survivals detoxify chemicals used as pesticides low kill-rate. "Pesticide treadmill"

Some Answers to Reducing Pesticide Use

- **Control populations – work within ecological principles, IPM**
- **Pest Control Advisors must use these practices, *an old idea*.**
  - **Select all the techniques to control pests.**
  - **Understand the ecological interactions of the pests.**
  - **More is not necessarily better…follow application guidelines strictly**

Pesticide Regulations Agriculture

- ALL pesticide applicators must have a license which they obtain by successfully taking a test. "Private Applicator's License"

- ALL Farm workers must use proper safety equipment – mask, gloves, safety glasses, coveralls. Must be trained in their native language.
- Pesticide storage is monitored.
- County Health Dept. – Hazardous materials, pay a fee annually.

Organic Foods

- Promoted as being "Healthier" because they're farmed without the use of pesticides right??
- Wrong! – organic farmers use pesticides! What's the difference?

Future Challenges?

- **IPM – "requires people to work smarter" dealing with biology & ecology and utilizing…**
  - **"Environmentally Friendly" pesticides**
- **<u>Organic Farming</u>**
- **"Biotechnology" – fear of the unknown, no risk is acceptable according to anti-biotech groups.**

Future of Chemicals & Pesticides

Alternatives will be Key Issue…not a new concept!

- **Beneficial insects**
- **Mechanical control**
- **Chemical controls**
- **Hedgerows – create a place for native species- self perpetuating**
- **Cover crops that produce nitrogen…lower fertilizer use**
- **Cover crops that encourage beneficial insects…**
- **Proper irrigation for various crops…reduce runoff**

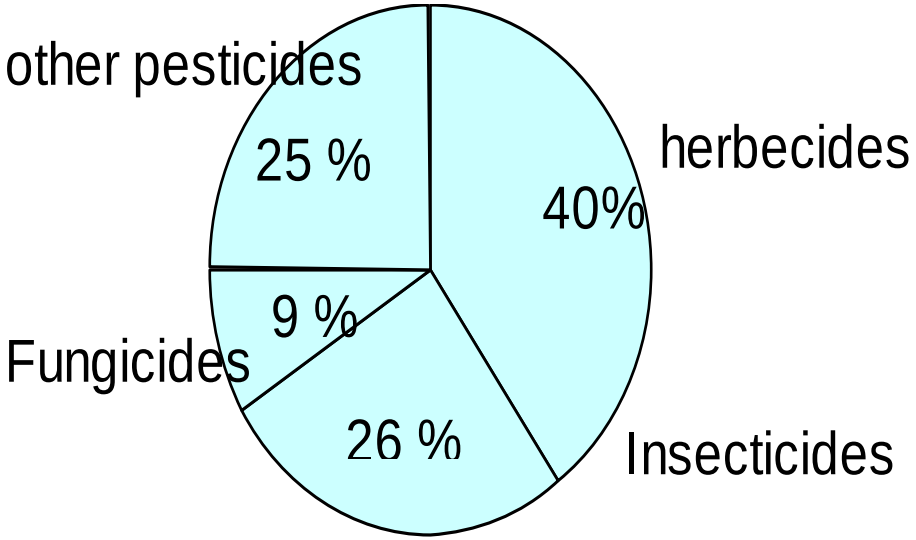
Class Discussion

- **What do you think are some of the greatest threats to using pesticides..?**
  - **In the Rift Valley**
  - **In Ethiopia**
  - **Globally**
- **What are some of the greatest benefits you see from using pesticides?**
- **Do you feel that we can ever live without pesticides/chemicals? Why, Why not?**
- **Do you think that we have a tendency to overreact in Ethiopia and are our laws and regulations justified?**

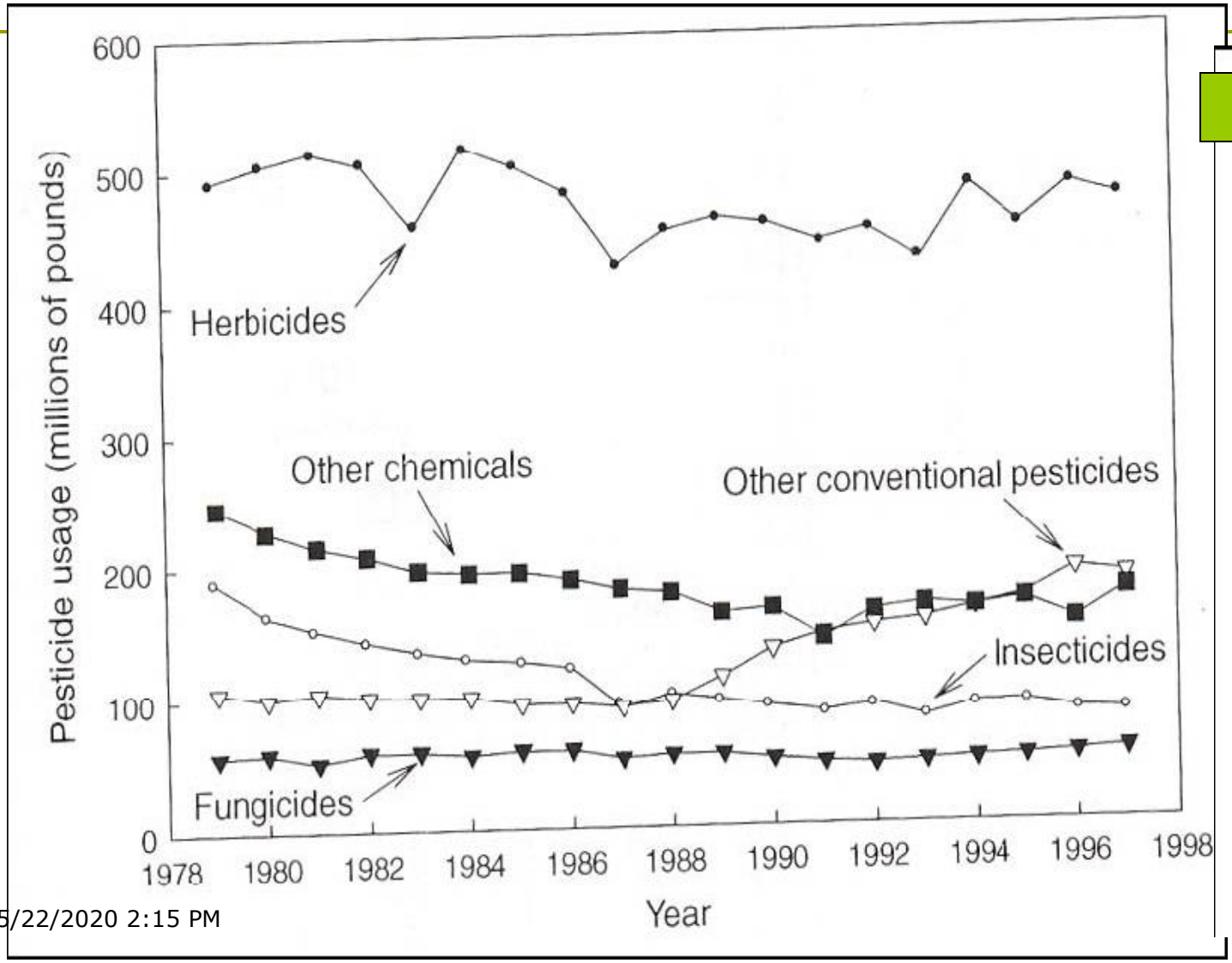
Advantages and disadvantages of pesticides

Advantages	**Disadvantages**
-May require less energy than other control measures	-Effect on non-target pest - External to the agro-ecosystem
-Require less knowledge of pest biology and agro-ecosystem process than do alternative tactics	-Cost of pesticides -Residue and drift -Food contamination
-Provide rapid remedial action against the target pest allow rapid control of an existing pest	-Toxicity
-Pesticide decrease the amount of planning required by the pest	**Create problems**: 1.Pesticide resistance
-Provide relatively greater predictable level of control	2. Pest resurgence
-Allow over greater control over cropping sequences	3. Secondary pest problems
-Some have permitted the development of new cultural practices. Eg. No-reduced-tillage	4. Pesticide treadmill: mis-use of pesticide may lead to more frequent applications and require higher rates of the product needed to control the same pest
-Can be used in every agro-ecosystem.	
-Reduced toxin in foods	

Worldwide production and use of pesticides (Aspelin and Grube, 1999)

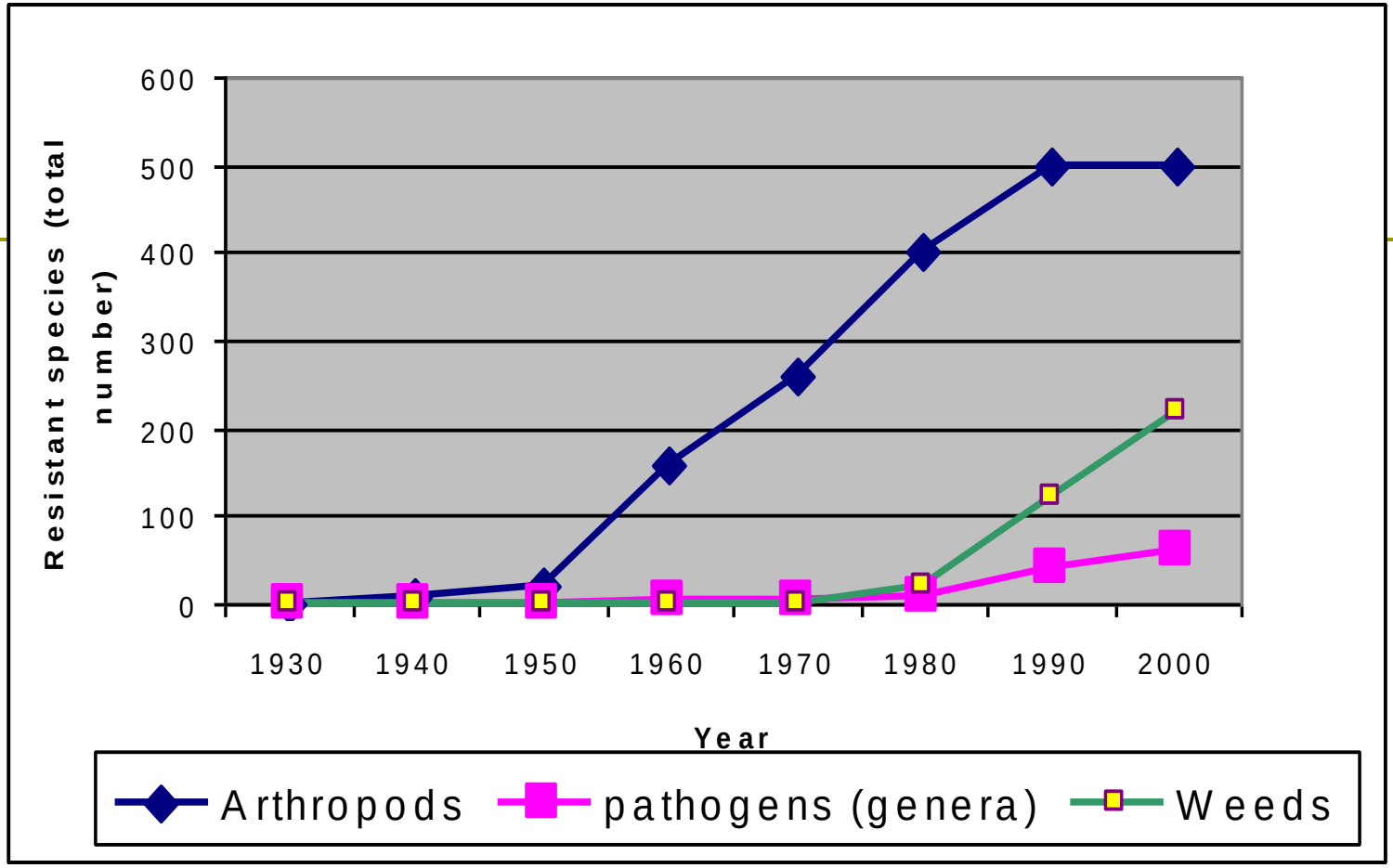


Use of Pesticides



Changes in use of major classes of conventional pesticides, including other chemicals such as growth regulators and desiccants, in the United States between 1978 and 1997.

Source: data by Aspelin and Grube, 1999.



Pest resistance to insecticides, fungicides and herbicides in relation to time. Data for pathogens are by genus. Modified from Georghiou and Laguens Tejeda (1991), Whalen (2001) and HRAC (2000).

US & World Use - 1997

Agriculture Based Pesticides

Volume of Active Ingredient (Billions of Pounds)

	U.S. Market		World Market	
Pesticide Class	(B lb.)	(%)	(B lb.)	(%)
Herbicides	0.57	46%	2.25	40%
Insecticides	0.13	10%	1.47	26%
Fungicides	0.08	7%	0.54	9%
Other[1]	0.45	37%	1.42	25%
Total	1.23	100%	5.68	100%

[1]Other - Dose not cover industrial wood preservatives, specialty biocides and chlorine/hypochlorites

Source: EPA OPP, 1997

1 kilogram = 2.20462262 pounds

US & World Use - 1997

Agriculture Based Pesticides

User Expenditures (Billions of Dollars)

	U.S. Market		World Market	
Pesticide Class	($ B)	(%)	($ B)	(%)
Herbicides	$6.85	58%	$16.89	46%
Insecticides	$3.55	30%	$11.59	31%
Fungicides	$0.80	7%	$6.04	16%
Other[1]	$0.70	6%	$2.53	7%
Total	$11.90	100%	$37.05	100%

[1]Other - Dose not cover industrial wood preservatives, specialty biocides and chlorine/hypochlorites

Source: EPA OPP, 1997

Problems

- **Bioaccumulate – example DDT**
- **35,000 or more commercial products that use pesticides**
- **Many pesticides are neurotoxic (affect the nervous system)**
- **Many kill desirable insects or plants**
- **Contaminate streams and lakes**

Absorption

Ingestion
Inhalation (lung)
Skin (dermal)

Home Exposure

- **Accidental ingestion**
- **Lawn and garden use**
- **Insect control**
- **Food supply**
- **Water supply**

Occupational Exposure

- Farms & Farm worker
- Pesticide applicator
- Manufacture
- Mixing and handling
- Landscapers
- Many more ……

Other Exposure

- **Dietary exposure**
  - **Pesticide residues on crops**
- **Community exposure**
  - **Airborne drift from commercial app**
- **Contaminated drinking water**
  - **Leaching from soils to ground water**