Integrated Pest Management of Cotton

Dr. Malik Saifullah M. Khokhar

Pests[1] are a serious impediment in cotton production. I will confine myself to insect only. More important pests belong to the sucking complex – plant hoppers/bugs: jassid, aphid, whitefly, mites, etc. and bollworms – pink, spotted/spiny bollworm, budworms and armyworms. They can be controlled by using several pest control methods and strategies:

- Chemical – Insecticides, fungicides, herbicides, avicides, rodenticides;
- Physical – Hand-picking, brooms/branches to beat pests;
- Cultural – Crop rotation, burning crop residues, intercropping; trap-cropping; plowing;
- Biological Controls: Introduction of new, and augmentation of existing natural enemies;
- Varietal Controls: Resistant plant varieties;
- Legislative Controls: Quarantine, control of movement of plants/plant materials, enforced rotation, destruction of crop residues;
- Others: Sterile male techniques, repellents/attractants, pheromones etc.; and
- Harmonic Control (Europe in 1960s): Integration without pesticides

Chemical have been used for pest control for centuries. Pesticides are poisons can be systemic (soluble in water-reaching insects through cell sap), contact (stomach poisons) and respiratory – and are potential hazards both for the environment and the users. They are an acute risk to health with single or multiple exposures over a relatively short period of time, encountered accidentally by handling products in accordance with the manufacturer's directions for handling or in accordance with the rules laid down for storage, transportation and use by competent international bodies. Pesticides are also non-point sources for pollution of surface and ground water. Thus the need for IPM methods.

Integrated Pest Management (IPM) is a mix of farmer-driven, ecologically based pest control practices seeking reduced reliance on synthetic chemical pesticides by:
- managing pests (population below economic thresholds);
- relying on non-chemical measures to keep pest population low; and
- In absence of alternatives, how to decrease adverse impacts and maximize benefits by selecting and applying pesticides with least adverse effects on beneficial organism, humans and environment.

Pesticides are **POISON**, and a potential Environmental hazard. They are an acute risk to health with single or multiple exposures over a relatively short period of time encountered accidentally by handling products in accordance with the manufacturer's directions for handling or in accordance with the rules laid down for storage and transportation by competent international bodies. There are many different types of chemicals used for pest control. These chemicals and there brief developmental history is as follows:

Criteria for selection and use of pesticides

(a) Negligible adverse human health effects.
(b) Be effective against target species.
(c) Minimal effect on non-target species & environment – Methods, timing, and frequency of application aimed; to minimize damage to natural enemies; and
Pesticides used in public health – safe for inhabitants, domestic animals and for personnel applying them.
(d) Prevent the development of resistance in pests.

---

[1] Pest: All biotic components of the crop environment capable of inducing stress and reducing crop yield or quality; Or species which is undesirable in certain space at a certain time.
We characterize other species of plants and animals as 'undesirable' because we wish to utilize resources for our benefit, excluding all other competitors.

Historical development of pesticides

1. Inorganic Insecticides
2. Botanical Insecticides
3. Modern Synthetic Chemicals
   - A: Chlorinated Hydrocarbons
   - B: Organophosphorus
   - C: Carbamates
   - D: Pyretheroids
   - E: Insect Growth Regulators
   - F: Formamidine Insecticides

Naturally Occurring Chemicals/Inorganic materials like salts, ashes, soot, dust, sulfur used for pest control for thousands of years.

Inorganic Insecticides: Arsenic + honey used as stomach poison for ants in the 1600s.
1800s: Paris Green (arsenical) to control Colorado potato beetle and other foliage feeding pests;
1920-40s were the days of Calcium arsenate ($Ca(AsO_4)_2$): Stomach poison inhibiting respiratory enzymes. Aerial dusting to control boll weevil – it did control, but outbreaks of secondary pests (aphids, bollworms, etc. due to destruction of natural enemies); Arsenic in soil led to low yields of arsenic sensitive crops (soybeans, etc.). Salts of mercury and lead were also used.

Botanicals: Nicotine (water extract of tobacco) contact nerve poison (agonist of nicotine acetylcholine receptors). Used since 1763. High human fatalities.

Others: Pyrethrum, derris, rotenone, sabadilla, ryania, hellebore etc.
Pyrethrum (chrysanthemum flower extract) is a contact nerve poison, and disrupts sodium channel function. It has a fast knockdown effect, but is highly photosensitive and has high bio-degradability. It was used extensively in 1800s during Napoleonic Wars (human body lice).

Modern Synthetic: Chlorinated Hydrocarbons: Paul Muller (1939) described insecticidal properties of a known chemical: Nerve poison with contact and stomach actions, broad spectrum with longer residual effect, hence was very economical pest control. He was awarded Nobel Prize for this discovery.

1962: 1200 formulations against 240 pests;
1963: peak production – 81m Kg;
1972: banned. Because of…Indeed this same chemical is now a nightmare!
…THIS CHEMICAL IS DichloroDiphenylTrichloroethane a.k.a. DDT.

DDT still available (US for louse control on humans – with physician's prescription) and manufactured in some countries (including China).

Modern Synthetic: Organophosphates: 1941: G. Schrader discovered schradan, a nerve poison inhibiting acetylcholinesterase. Parathion was introduced in 1944. Organophosphates are contact, stomach, systemic poisons and fumigants. Other famous OPs: malathion, dimethoate, diazinon, profenofos, etc.

Organophosphates – Comparison with Hydrocarbons! Dissimilarities:

	Organophosphates	**Chlorinated Hydrocarbons**
Persistence	**Less**	**More persistent**
Biodegradability	**Faster**	**Very slow**
Mammalian Toxicity	**Higher**	**Relatively lower**

Organophosphates – Similarities with hydrocarbons:
They both led to the emergence of secondary pests; resurgence of target species; destruction of beneficial species, and development of insect resistance to these chemicals.

Modern Synthetic: Carbamates: Synthetic analogues of plant alkaloid physostigmine, have stomach, nerve poisons inhibiting activity of acetylcholinesterase with contact and systemic activity, are relatively nonpersistent; do not bioaccumulate. Carbaryl: 1956, broad spectrum, low mammalian toxicity. methomyl, aldicarb, thiocarb, propoxur, carbofuran etc

Modern Synthetic: Pyrethroids: 1972 Permethrin (synthetic and photo stable) was effective at rates of 10-100 times less than OP and chlorinated hydrocarbons. Pyrethroids are axonic nerve poisons, similar to DDT in their mode of action hence – cross resistance. Examples: Fenvalerate, cypermethrin, bifenthrin etc.

Modern Synthetic: Insect Growth Regulators: Structure of first juvenile hormone elucidated in 1967. Very few products because of slow mode of action. Mimics/analogues. Methoprene kills by inhibiting molting benzoylphenylureas – interfears with chitin synthesis.

Modern Synthetic: Formamidine Insecticides: Only two commercially successful formamidines: amitraz and chlordimeform. EPA cancelled the latter - chronic toxicity to humans. Mode of action: ovicidal via contact and vapor, synergism of many classes of insecticides and modification of insect behavior. Sublethal effects include disruption of feeding and reproduction, functioning as octopamine agonists.

Novel Chemicals:
A: Avermecitin: most potent insecticides/acaricides; disrupts GABA (ligand-gated) and chlorine channels on nerves.
B: Pyrrole: Pirate insecticide/acaricide is a lead based uncoupler of oxidative phosphorilation.
C: Phenylpyrazole: Fipronil, a potent blocker of GABA-gated chloride channel makes it effective against insects resistant to carbamates, organophospates & pyrethroids.
D: Chloronicotinyl insecticide:
E: Spinosyn Insecticides
F: Bacillus thuringiensis Insecticides
G: Insect Growth Regulators

WHO Classification: LD50				
WHO Class	Oral	Dermal		
	Solids	Liquids	Solids	Liquids
Ia Extremely hazardous	5 or <	20 or <	10 <	40 <
Ib Highly hazardous	5 – 50	20 – 200	10 – 100	40 - 400
II Moderately hazardous	50 – 500	200 – 2000	100 - 1000	400 - 4000
III Slightly Hazardous	Over 500	Over 2000	Over 1000	Over 4000

[2]

[2] **LD50:** Statistical estimate of number of milligrams of toxicant per kilogram of body weight to kill 50% of a large population of test animals

Why Classification of Pesticides!

- Distinguish between more and less hazardous forms of each pesticide (formulation vis-à-vis A.I.);
- Where dermal LD50 value of a compound is such that it would place it in a more restrictive class than the oral LD50 value would indicate, the compound will always be classified in the more restrictive class;
- There may be other considerations besides the LD50

Class 1A: Extremely hazardous.

Alachlor: $C_{14}H_{20}ClNO_2$ Herbicide, carcinogenic: rat &mice
Captafol: $C_{10}H_9NO_2S$ Fungicide, carcinogenic: rat & mice
Hexachlorobenzene: C_6Cl_6 Fungicide, carcinogenic, foetotoxic and teratogenic
Parathion: $C_{10}H_{14}NO_5PS$ Insecticide/acaricide, Fostox
Methyl parathion: $C_8H_{10}NO_5PS$ Insecticide, Folidol
Phosphamidan: $C_{10}H_{19}ClNO_5P$ Insecticide, Dimecron

Class 1B: Highly hazardous

Dichlorovos $C_4H_7Cl_2O_4P$ Nogos, Vapona, Phosvit, Swing
Dicrotophos $C_8H_{16}NO_5P$ Bidrin Toxic to bees and birds
Methamidophos $C_2H_8NO_2PS$ Toxic to fish, birds, bees
Monocrotophos $C_7H_{14}NO_5P$ Azodrin, Nuvacron
Nicotine $C_{10}H_{14}N_2$ Nico Soap
Zeta-cypermethrin $C_{22}H_{19}Cl_2NO_3$ Fury

Class II, Moderately Hazardous:

Formulations/chemicals in Class II include:
Chlordane (POP*) $C_{10}H_6Cl_8$ Octachlor half life in soil 1 year
Chlorpyrifos $C_9H_{11}Cl_3NO_3PS$ Dursban
Cypermethrin $C_{22}H_{19}Cl_2NO_3$ Arrivo, Cymbush
DDT (POP) $C_{14}H_9Cl_5$ dichlorodiphenyltrichloroethane
Endosulfan $C_9H_6Cl_6O_3S$ Fan, Thiodan, Endocel
Heptachlor (POP) $C_{10}H_5Cl_7$ Carcinogenic
Paraquat $C_{12}H_{14}Cl_2N_2$ Herbicide Gramoxone

Why be wary! Monitor, Tamaron, Patrole, Edron, Pilaron are multiple trade names of the "same" organophosphorus – methamidophos, Acutely toxic to bees, birds and fish; and have delayed neuropathy, and is WHO Class 1B (Highly hazardous). Sometime there are 15 or more trade names for one active ingredient in a country.

Why Chemical Control?

Crop Protection a New phenomenon?
Modern Agriculture!?!
Are chemical pesticides the only panacea?
Arthropod Resistance to Chemicals!!!

WHY IPM? Some Pesticide Facts: Agrochemical sales in 2000 US$ 29.9

Chemical Pesticide Market share (by region)

Asia/Pacific		25.4%
Latin America		12.8%
North America	29.6%	
Western Europe	21.9%	
Rest of the World		10.3%

Is crop protection new? No. What is new is the fact that Crop Protection now is a "Big Business **(**Pesticides sales: about US$30 billion a year)

Over 80% of global pesticide market shared by 8 companies: Aventis, BASF, Bayer, Dow AgroSciences, Dupont, Monsanto, Sumitomo and Syngenta

Major producers: Europe, US, Japan, China, India. Large sums of money involved in pesticide trade. Variety of hidden interests play a role in decisions concerning pesticide procurement or donation. Link between pesticide trade – solution to pest problems is perfect.

Have we reached the end of the road?

Movement to low application rates of product/area… much development possible.
Application methodology:
18.5 mg of cypermethrin required to kill 95% of an extremely high population (100,000 larvae/Ha) of tobacco budworm… we use roughly 3500x this amount!

Integration of chemicals and other approaches of Pest Management

Production practices: variety, planting dates, fertilization, irrigation, conservation tillage, crop residue destruction, etc.

Compatibility of chemical control with other approaches: facilitating IPM – crop production practices, selective pesticides, biorational approach and ecological selectivity

Factors of resistance:

1. Genetic: frequency, number and dominance of genes for resistance and their fitness
2. Biological: generation turnover, number of progeny, refugia, migration
3. Operational: chemical nature, persistence of chemical, stage of life cycle of pest

1 and 2 are mostly beyond human control, but 3 can be manipulated.

Application!!!

Application: conventional spray 9.4-94 L/Ha
Ultra Low Volume (ULV) 1.9L/Ha or less
    Problems: atomization, uniformity of dispersal, drift
Drift – 0ff-target movement: up to 50% lost by aerial spraying
Novel delivery: slow (controlled) release formulations
Chemigation: pesticide application through irrigation