

MoA (Mode of Action) is HOW an insecticide kills !

All pesticides enter insects through Dermal, Oral or Respiratory routes.

There are **28 known MoA groups + 7 unknown MoA groups** (these include inorganic, oils, soaps, etc.).

PLEASE see suggested handout:

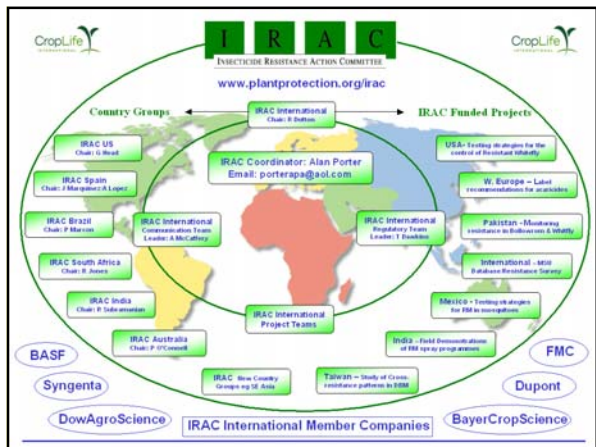
IRAC Mode of Action List

IRAC = Insecticide Resistance Action Committee

Version 5.3

www.irac-online.com

Since 1984



Modified IRAC MoA List

Site / Type of ACTION = Where in pest ?

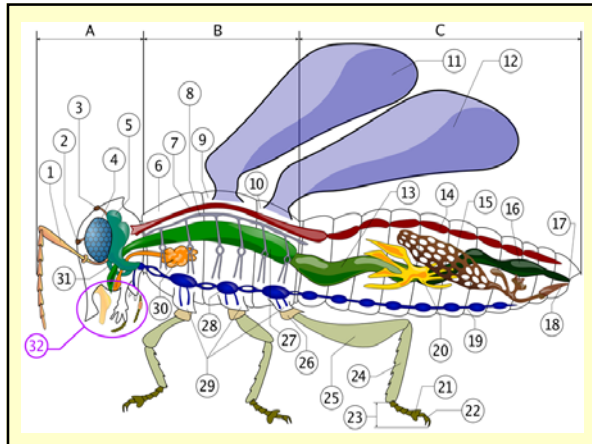
MoA Group = #

Sub-Group = Letter

Chemical Class / Sub-Group

Botanicals	Organochlorines
Carbamates	Organophosphates
InOrganics	Synergists

Examples of Active Ingredients





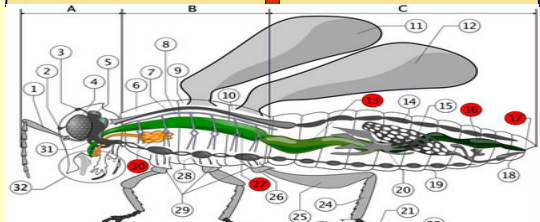
“To understand the success of insects is to appreciate our own shortcomings.” T.Eisner

Dr. T. Eisner, Prof. of Chemical Ecology, Cornell University. A world authority on animal behavior, ecology, evolution and author or co-author of some 400 scientific articles and 7 books on chemical interactions of organisms.

Humans	Insects
One species	Over 1,000,000 species
Cause harm to others of the <u>same species</u> and to others of different species.	Cause harm only to others of different species.
Developed brain (at least the potential exists) & speech .	Minimal brain capabilities & some can communicate via verbalization.
Fly via special equipment.	Over 97% can fly on their own as adults.

Humans	Insects
Long life span, some > 100 yrs.	Short life span, = days to months.
Limited sense of smell & taste.	Great sense of smell & taste.
Offspring = 2 – 3 is most usual.	Offspring = over 300 is normal.
Typically dependent upon others to produce their food and provide a variety of services to enable life.	Typically “ fend for themselves ”, find their own food, water and shelter & only a few depend on others via colony life and specialized activities.

Skeletal & Muscular	
Humans	Insects
Internal to skin , with 206 bones which are key in blood production and provide body support.	External to body , durable exterior of ALL Arthropods, composed of chitin and protein, but with flexible joints.
Human body has around 640 named muscles and they weigh about 40% of the average body.	A caterpillar has about 4,000 muscles and 248 of these are in the head. Based on size, insects are MUCH stronger than humans.
	

Digestive System	
Humans	Insects
Basically a 30 foot long, twisted tube with esophagus, stomach, small and large intestine + liver.	Basically a straight tube with 3 basic regions: fore-gut, mid-gut and hind-gut.
	

Nervous System

Humans	Insects
<p>Dorsal system, centralized brain function, response acts are made by brain.</p>	<p>Ventral system, with brain mass and up to 11 ganglia.</p>

Circulatory System

Humans	Insects
<p>CLOSED system of one heart, arteries, veins and capillaries to carry O₂ to cells.</p>	<p>OPEN system with a DORSALLY located Aorta, NO veins or arteries, many "hearts", hemolymph is about 90% of watery plasma + 10% hemocytes.</p>



Respiratory System

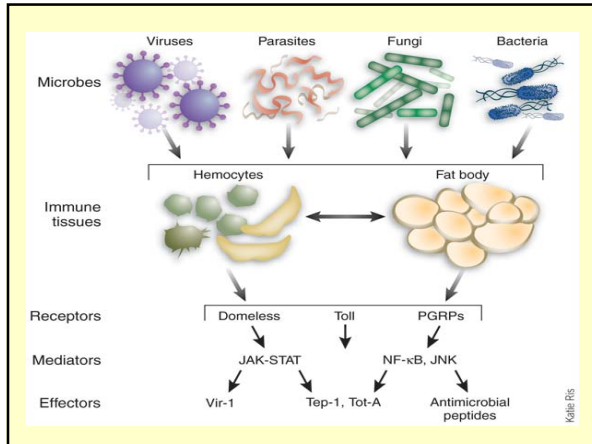
Humans	Insects
<p>CLOSED system. Air enters into lungs where blood has O₂ added and CO₂ removed.</p>	<p>OPEN system. NO lungs. Spiracles let air into limited network of trachea. O₂ not carried by blood!</p>

Reproductive System

Humans	Insects
<p>Male and Female organs on separate individuals (in most cases). 1:1 sex ratio.</p>	<p>Male and Female organs on separate individuals, but females are the main sex found in many insect groups</p>

Fat Bodies

Humans	Insects
<p>Storage area from excessive caloric intake as related to the actual needs of the body.</p>	<p>Major metabolism area + nutrient storage. Like human liver in function, synthesizes proteins, carbohydrates & lipids that circulate in insect blood. Protection of body.</p>



Excretory System

Humans	Insects
<p>Kidneys remove excess liquid & excretory products, then passed to bladder & discharged. Solid feces are usually moist !</p>	<p>Malpighian tubules are key excretory organs. metabolized & waste cmpds. circulating in hemolymph are absorbed, solid waste is usually dry.</p>

Endocrine System

Humans	Insects
<p>Regulates a diverse array of physiol. & biochem. processes.</p>	<p>Hormones regulate diverse physiological & biochem. processes.</p>

Modified IRAC MoA List

Site / Type of ACTION

MoA Group

Sub-Group

Chemical Class / Sub-Group

Botanicals	Organochlorines
Carbamates	Organophosphates
InOrganics	Synergists

Examples of Active Ingredients

Site of Action:

Nervous system

- Cholinesterases Inhibitors OP, Carbamates
- Acetylcholine Receptor Stimulation Neonic., Spinosad
- Chloride Channel Regulation Avermectins, GABA rec.
- Sodium Channel Modulators Pyrethrins, Pyrethroids

Endocrine system

- Chitin Synthesis Inhibitors Buprofezin, Larvadex, Diflubenzuron, Hexaflumuron, Lufenuron,
- Growth Regulators / JH Fenoxo., Hydro., Methopr.
- Non-specific Growth Regulators Carboxamide

Site of Action:

Energy Produc. (ATP) & Metabolism

Hydramethylnon (baits), Pyrroles (Phantom), Neemex,

Bt (Microbial), Azadirachtin, Cryolite (block feed.)

Rotenone, Botanicals / Hort. Oils, Soaps,

Miscellaneous NON-SPECIFIC

Multi-site = Argenicals, Boric Acid

Repellent = Kaolin

Silica gel (Drione® - absorbs waxes fm insect body)

Modified IRAC MoA List

Site / Type of Action	Nervous = Acetylcholine esterase inhibitors
MoA Group	1
MoA Sub-Group	1A
Chem. Class Sub-Group	Carbamate
Examples of Active Ingredients	Aldicarb, Bendiocarb , Carbaryl , Isoprocarb, Methomyl, Propoxur

Modified IRAC MoA List

Site / Type of Action	Nervous = Acetylcholine esterase inhibitors
MoA Group	1
MoA Sub-Group	1B
Chem. Class Sub-Gp.	Organophosphates
Examples of Active Ingredients	Acephate, Chlorpyrifos , DDVP , Diazinon , Malathion , Parathion

Insecticide acts to “tie up” acetylcholinesterase and this results in an “overloading” of the nerve synapses so that there is

A RAPID FIRING OF NERVE IMPULSES

resulting in: convulsion,
paralysis,
respiratory failure, and
death

Modified IRAC MoA List

Site / Type of Action	Nervous = GABA-gated chloride channel antagonists
MoA Group	2
MoA Sub-Group	2A
Chem. Class Sub-Group	Cyclodienes / organo-chlorines
Examples of Active Ingredients	Chlordane , Endosulfan, Lindane

Modified IRAC MoA List

Site / Type of Action	Nervous = GABA-gated chloride channel antagonists
MoA Group	2
MoA Sub-Group	2B
Chem. Class Sub-Gp.	Phenylpyrazoles
Examples of Active Ingredients	Ethiprole and Fipronil

Effects on Insects:

Hyperactivity, tremors, convulsions, staggering, difficulty breathing, nausea, vomiting, diarrhea, lack of coordination, unconsciousness, paralysis and death.

Cross-resistance issues !



Modified IRAC MoA List	
Site / Type of Action	Nervous = Sodium Channel Modulators
MoA Group	3
MoA Sub-Group	A / B
Chem. Class Sub-Group	DDT, Methoxychlor, Pyrethroids
Examples of Active Ingredients	DDT, Methoxychlor, Allethrin, Bifenthrin, Cyfluthrin, Cypermethrin, Deltamethrin, Permethrin, Resmethrin

The RIGHT formulation of the pyrethroid is KEY !

- A. Aerosol = Liquid or semi-solid (gel, foam paste) in can
- B. Bait - block - gel - paste
- foam - liquid - granular
- C. Chinese Chalk
- D. Dust
- E. Fumigants = Solids or Compressed
- F. Lacquers
- G. Liquids - EC = Emulsifiable Concentrate
- SC = Suspendable Concentrate
- **ME = Micro-Encapsulated / CS**
- H. WP = Wettable Powder or WG = Wettable Granule

Effects on Insects:

Stimulates repetitive nerve discharges, sometimes called

“TWITCHING or DDT Jitters”

leading to Paralysis & Death

Modified IRAC MoA List	
Site / Type of Action	Nervous = Nicotinic Acetylcholine receptor agonists / antagonists
MoA Group	4
MoA Sub-Group	4A
Chem. Class Sub-Gp.	Neonicotinoids
Examples of Active Ingredients	Acetamiprid, Clothiamidin, Dinotefuran, Imidacloprid, Thiacloprid, Thiamethoxam

Modified IRAC MoA List	
Site / Type of Action	Nervous = Nicotinic Acetylcholine receptor agonists / antagonists
MoA Group	4
MoA Sub-Group	4B
Chem. Class Sub-Gp.	Nicotine
Examples of Active Ingredients	Nicotine

Effects on Insects:

Targets INSECTS, not mammals, increased or decreased heart rate, excitation, convulsions, paralysis and death

Modified IRAC MoA List

Site / Type of Action	Nervous = Nicotinic Acetylcholine receptor allosteric activators agonists ≠ Group 4
MoA Group	5
MoA Sub-Group	
Chem. Class Sub-Gp.	Spinosyns
Examples of Active Ingredients	Spinosad

Spinosad was developed from a soil bacteria found in an abandoned rum distillery on a Caribbean Island.

It actually is the “by-product” of a bacterial fermentation process in a mixture of: corn, cottonseed flour, soybean flour, glucose, methyl oleate and calcium carbonate.

Since it is of “an organic origin” it can be used in organic farming / gardening areas.

Effects on Insects:

Spinosad is also a acetylcholine receptor agonist but acts in a but different way from the neonicotinoid group.... but with the same end results.

Increased or decreased heart rate, excitation, convulsions, paralysis and death.

Modified IRAC MoA List

Site / Type of Action	Nervous = Chloride Channel Activators
MoA Group	6
MoA Sub-Group	
Chem. Class Sub-Gp.	Avermectins
Examples of Active Ingredients	Abermectine, Emamectin benzoate, Milbemectin

Effects on Insects:

Avermectins bind to the chloride channel. Normally, this channel blocks the reactions in some nerves, preventing excessive stimulation of the CNS (Central Nervous Sys.).

Avermectins activate the chloride channel, causing an inhibitory effect, that will, when in excess, result in death of the insect.



Modified IRAC MoA List

Site / Type of Action	Endocrine = JH Mimics
MoA Group	7
MoA Sub-Group	A / B / C
Chem. Class Sub-Group	IGR = Insect Growth Regulators
Examples of Active Ingredients	Hydroprene, Methoprene, Fenoxycarb, Pyriproxyfen

Effects on Insects:

Juvenile Hormone Mimics (IGR) disrupt molting process of insects, so that immature insects do NOT become adults !

Other MoA Groups which impact Growth:

- Gp 10 Mite growth inhibitors
- Gp 15 Chitin biosynthesis inhibition Type 0 (Isoptera and Lepidoptera)
- Gp 16 Chitin biosynthesis inhibition Type 1 (Homoptera = true bugs)
- Gp 17 Molting disruption (Diptera = flies)
- Gp 18 Ecdysone receptor agonists (Halofenozide)

Modified IRAC MoA List

Site / Type of Action	Microbial disruptors of insect mid-gut membrane
MoA Group	11
MoA Sub-Group	5 groups
Chem. Class Sub-Group	Microbial
Examples of Active Ingredients	<i>Bacillus thuringiensis</i> = 4 types and <i>Bacillus sphaericus</i>

Effects on Insects:

The impact of these microbes is to produce a crystal that is toxic to some insects.

When Bt is consumed by larva, there is an attack on the lining of the insect mid-gut that causes it to STOP feeding and the insect ultimately dies !

Modified IRAC MoA List

Site / Type of Action	Uncouplers of oxidative phosphorylation via proton gradient disrupt.
MoA Group	13
MoA Sub-Group	
Chem. Class Sub-Gp.	Chlorfenapyr and DNOC
Examples of Active Ingredients	Chlorfenapyr and DNOC

Effects on Insects:

By uncoupling the oxidative phosphorylation from electron transport, the end result is that the cells are unable to produce energy (called ATP = Adenosine Tri-Phosphate) for energy in the insects.... & they “run out of gas”.

Modified IRAC MoA List

Site / Type of Action	Endochrine = Inhibitors of chitin biosynthesis
MoA Group	15
MoA Sub-Group	
Chem. Class Sub-Group	Benzoylureas
Examples of Active Ingredients	Diflubenzuron, Hexaflumuron, Lufenuron (Zyrox), Novaluron, Noviflumuron

Effects on Insects:

This group of Juvenile Hormone Mimics (IGR) directly inhibit biosynthesis of chitin (EXOSKELETAL).

Commonly used to manage:

- Isoptera = Termites
- Lepidoptera = Moths and Butterflies

Modified IRAC MoA List

Site / Type of Action	Mitochondrial Complex III electron transport inhibitor
MoA Group	20
MoA Sub-Group	A / B / C
Chem. Class Sub-Group	Amidinohydrazone
Examples of Active Ingred.	Hydramethylnon, Acequinocyl, Fluacrypyrim

Effects on Insect:

Impact Mitochondria and energy production in the insect’s Krebs Cycle.

The impacted insects basically “run out of energy” and die on their feet.



Modified IRAC MoA List

Site / Type of Action	Nervous = Voltage-dependent sodium channel blockers
MoA Group	22
MoA Sub-Group	A / B
Chem. Class Sub-Group	Oxadiazines
Examples of Active Ingredients	Indoxacarb , Metaflumizone

Effects on Insects:

Voltage-dependent sodium channel blockers are finding a solid place in management of ants, cockroaches and other urban pests.



Modified IRAC MoA List

Site / Type of Action	Miscellaneous NON-SPECIFIC, multi-site actions / inhibitors
MoA Group	n.s. = non-specific
MoA Sub-Group	a / b
Chem. Class Sub-Group	Inorganics
Examples of Active Ingredients	Arsenic , Borax , Boric acid , Copper , Diatomaceous earth (Silica gel)

Effects of BORIC ACID on Insects:

Multi-site actions on various insect systems –

- **cytogenic** (kills cells) to most cells,
- destroys lining of the fore-gut,
- has desiccant properties,
- impacts the nervous system,
- impacts waste elimination,
- kills bacteria in gut,
- rapidly enters blood and gels it up,
- reproductive impact = sterilization,
- wettable and still remains active.

Boric Acid is:

- A compound mined from the earth,
 - A dust that provides long-term control,
 - An excellent cockroach control product,
 - Easy to apply in sensitive areas,
 - Effective at low doses,
 - Inexpensive,
 - NON-repellent,
 - NON-staining,
 - NON-volatile,
 - Odorless,
 - Safer than salt (LD-50 as per Merk Index 5,14 g/kg B.A. Vs. 3.75 g/kg SALT)
- To kill a 70 kg person would require 350 gm to 1,400 gm (0.77 – 3.08 lbs of 99% B.A.)

Boric Acid vs. Silica Aerogel

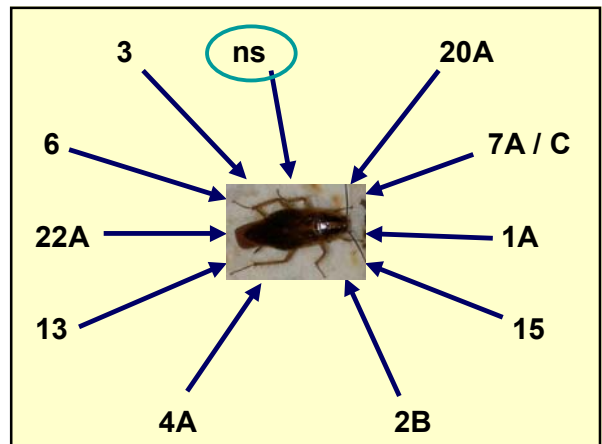
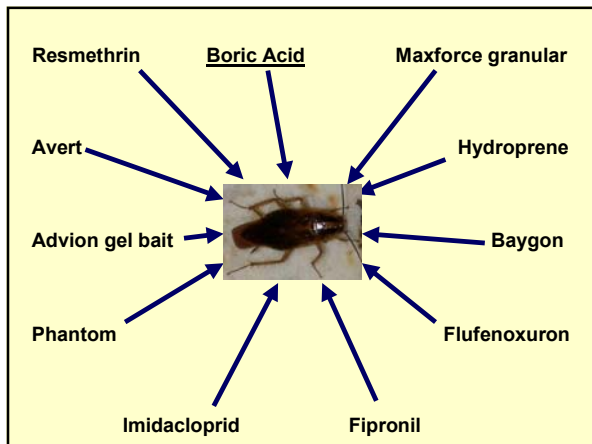
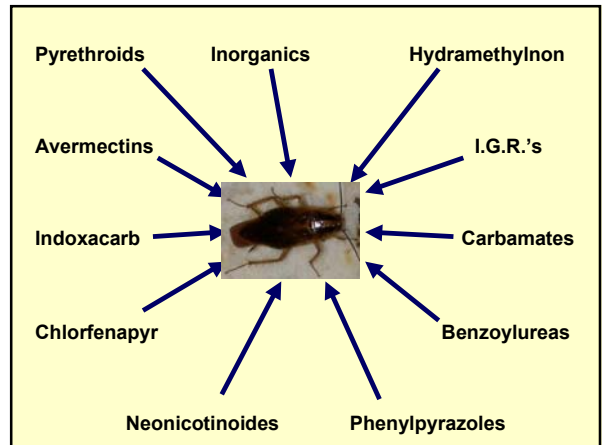
Borax and Boric Acid were found to be 7.1 time more effective than silica aerogel in killing German cockroaches even though the s.a. kills them 11 times more rapidly.

W. Ebeling 1966

Use of Dusts



Avoid Insecticide Resistance with Cockroaches



Remember:

1. **Insect resistance** results from using chemicals within the same group, sub-group, active ingredients or products.
2. Rotate insecticides from **different MoA** main groups as a part of your pest management programs.
3. Tank mixing of chemicals for one target pest can result in resistance being developed to both chemicals at once.
4. Insecticides **ARE NOT** just "magic liquids", actually they can alter short and long term bodily functions of arthropods, mammals and other animals. Be sure to **ALWAYS use the correct protective equipment**, especially when handling the concentrated products.

Remember: Use other IPM components in any cockroach management program !



1. Education
2. Inspection & I.D.
3. Exclusion
4. Cooperation
5. Trapping
6. Sanitation
7. Mechanical Control
8. Physical Control
9. Professionalism
10. Chemicals & Equip
11. Quality Assurance
12. Documentation

"Although resistance in German cockroaches is wide-spread, different application methods (e.g. baits and sprays {also dusts}) using **different modes of action classes** rather than the same classes of insecticides should be used in a rotational strategy to control the problem and delay the rapid development of resistance in all species."

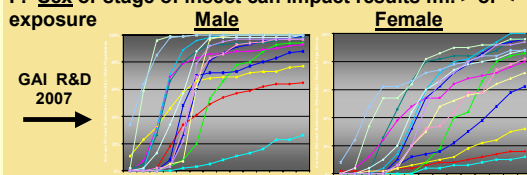
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Some Reasons Insecticides MAY Still NOT Work:

- A. Applicator ERROR on WHERE & HOW products are applied.
- B. Contamination by cleaning agents, repellents, water.
- C. Poor coverage or distribution of applied products.
- D. Cross-Resistance, a BEHAVIORAL or GENETIC basis.
- E. Sanitation, a combined type of contamination and sorption.

F. Sex or stage of insect can impact results fm. > or < exposure



G. Sorption = grease, unpainted wood, other surfaces

Stainless Steel	Ceramic Tile	Painted Wood	Unpainted Wood	Cloth
Low				High

H. Specificity, product used on wrong target pest.

Formulations:

- A. Aerosol = Liquid or semi-solid (gel, foam paste) in a can
- B. Bait - block - gel - paste
- foam - liquid - granular
- C. Chinese Chalk
- D. Dust
- E. Fumigants = Solids or Compressed
- F. Lacquers
- G. Liquids - EC = Emulsifiable Concentrate
- SC = Suspendable Concentrate
- ME = Micro-Encapsulated
- H. WG = Wettable Granule
- F. WP = Wettable Powder
- I. RTU or OTH

General Mixing Process for Liquid Pesticides

Needed Elements =

Applicator (YOU) with good training
Water
Chemical
Measuring Device
Paper Towels
Soap and Water
Trash receptacle
Personal Protection Equipment =
boots, face mask, gloves, goggles
Environmental Protection Items / Spill Kit
* Oil Cloth * Spill Control Products / Kit
* Plastic Bags

The Process, part 1

Extend plastic or oil cloth on a clean surface OUTSIDE & place sprayer on top

ADD half of needed water to tank (mix just what you will need !)

Gloves on, pick up product container and CONFIRM mixing rate

Open and measure needed chemical, TRIPLE rinse measuring cup

Agitation of half-filled applicator (use care, top is open)

The Process, part 2

Add additional water and close sprayer

Agitate fully and now you can pressurize the equipment

Test spray pattern onto test area (double layer of paper towels)

Be sure NO leaks are present, enter area to be treated

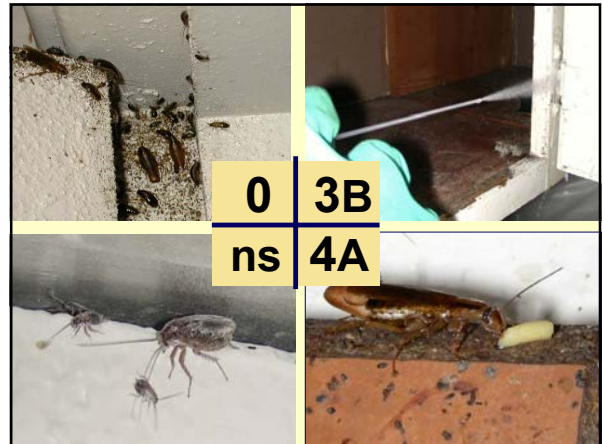
Apply spray with great care, avoid contamination situations !

Application process should be FOCUSED:

- A. Right place
- B. Right Time of Day
- C. Right Environmental Conditions
- D. Right Quantity / Concentration

Environmental Aspects:

- A. Measurements = ppm & < !
- B. Off target surfaces
- C. Water (run-off)
- D. Food
- E. People (young & old)
- F. Pets (cats & fish)



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Insecticide MoA

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