Section 7: Application of insecticides

- Use of the correct application procedures, as with selection of the formulation, can prove to be as important, or more important, than the selection of the toxicant.
- It is a surprisingly difficult engineering challenge to get the toxicant from the applicator to the target effectively.

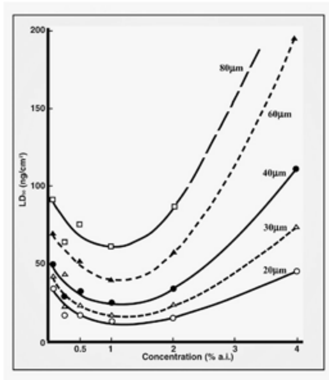
Targets

- Common targets for application include:
  - Plants (both crops and weeds)
  - Soil (surface and subsurface)
  - Water (usually the surface)
  - Walls and other interior and exterior surfaces, including below the foundation of buildings
  - Livestock and pets
  - The pests (resting, crawling, and flying; mobile and immobile stages)

Liquid applications: droplet size

- Most insecticide is applied as liquids, and the size of the droplets is an important element in determining effectiveness.
- Normally we strive for more small droplets - which provides better coverage and greater likelihood of contact.
- Large droplets tend to bounce off plant leaves and coalesce into even fewer, larger droplets.

This graph shows the effects of droplet size (diameter in microns) on the dose necessary to kill mite eggs. Note that the optimal concentration of pesticide (dicofol) is about 1%, but that the dose needed to induce 50% mortality is less when small droplets are applied (adapted from Munthali 1981).



Number of droplets per cm of ground that could be obtained by application of one liter of liquid distributed uniformly by drops of different sizes. Note the inverse relationship between droplet size and droplet number.

Diameter of drops	Drops per unit ground
10	20,000
20	2,400
50	153
100	19
200	2.4
500	0.3

Liquid applications: droplet size

- However, small droplets have their disadvantages:
  - Under hot, dry conditions they may evaporate before striking the target
  - Are more influenced by air movement, and move up or away from the target

To avoid these issues, early morning and early evening applications are common. Also, some applicators take advantage of cross-winds to enhance coverage.

Liquid applications: droplet size

- Most applicators produce a wide spectrum of droplet sizes. Those with a diameter of 30-50 microns are good for impinging on insects, whereas the 100-150 micron sizes are good for foliage treatment.
- Nozzles can be changed to affect droplet diameter
- Regardless of approach, applications are quite inefficient, and often only 1% of the volume applied actually reaches the desired target.
- Normally we can’t see small droplets, so for field assessment, oil or water sensitive cards which change color are used to appraise droplet size and coverage.

Classification of dispersed insecticide

Spray Pattern	**Micron size range**
Course spray	400 and larger
Fine spray	100-400
Mist	50-100
Aerosol and fog	0.1-50
Fumes and smokes	0.001-0.1
Vapor	Less than 0.001

Types of sprayers

Liquid

- Hydraulic
  - Pump forces large volume of liquid through nozzle with pressure; manual or engine-powered.
  - Liquid in reservoir may or may not be under pressure.
  - Nozzles usually produce fan or cone patterns.
  - Numerous modifications.
  - Some are relatively inexpensive, but require large volume of water.

The typical small compressed air sprayer (left) is powered manually, as are many backpack sprayers. However, the backpack sprayer below has a small engine.

Liquids can be injected into small spaces that are, or might be, inhabited by insects. Here you see a liquid that foams following injection, and expands to fill the void created by termites.

Mechanical, high-volume hydraulic sprayers find many uses in landscape maintenance.

Termite treatment sometimes requires perimeter application of insecticide around structures. Here you can see trenching around the building (above) followed by low-pressure application of liquid insecticide (below) to the soil.

Application of insecticide beneath the slab foundation of structures is more challenging, and requires drilling and injection of liquid formulations.

Hydraulic sprayers are widely used in agriculture. Here you see some adaptations to improve coverage of foliage: the plants are being sprayed from above, from the side, and from below (USDA, ARS).

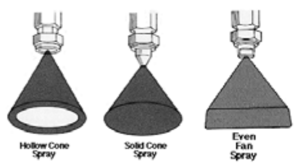
Sometimes insecticides are distributed along with irrigation water, a technique called chemigation or insectigation. Special regulators are required to assure that the insecticide does not siphon back into the water supply.

Some crops are grown on beds covered with plastic mulch. Insecticides and other pesticides may be injected into the soil at the time the plastic is laid, or injected afterwards through the drip irrigation systems

Aircraft, both fixed-wing and helicopters, are often used where large acreage is involved

For outbreaks on a large scale, such as occurs with grasshoppers and mosquitoes, aircraft are the only feasible means of rapid suppression. Larger, specially-modified cargo aircraft typically are used due to the need to carry large payloads.

Regardless of the type of hydraulic delivery, the nozzle type and placement are important in determining outcome. There are numerous types, but the basic nozzles are shown here.

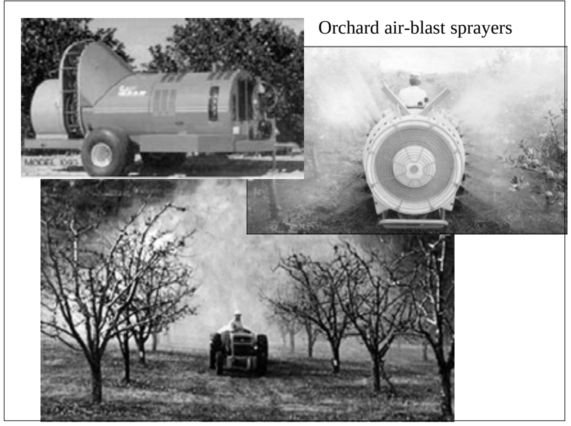


- Mistblowers
  - A large fan delivers a high volume of air, at high speed
  - Liquid containing insecticide is dripped into the stream of air
  - Mostly small droplets are produced, and distance of carry is limited
  - Usually fairly expensive equipment
  - Orchard air-blast sprayers, and twin orifice or spinning disk sprayers, are variations

Mistblowers come in many forms and have many uses. Their flexibility is one reason they are popular. Here you see backpack, truck and ATV-mounted units.

Shown are some applications of mistbowers, including insecticide treatment of windbreak trees, a rice paddy, and livestock .

Orchard air-blast sprayers



- Foggers
  - Two types: cold and thermal foggers
  - Cold foggers not much different than small mist blowers; use air to propel droplets
  - High volume of product may be used
  - Thermal foggers introduce insecticide into heated exhaust
  - Foggers may be hand-held or mounted on vehicles, including aircraft
  - Not much ability to provide direction
  - Visible to user, hence “fog” designation

Foggers may be large or small, and have interior and exterior uses.

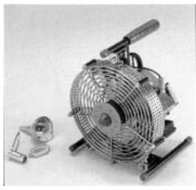
- Ultra-Low-Volume
  - Concentrated insecticide applied in small droplets
  - No dilution of insecticide
  - Little product applied per unit area
  - No visible “fog”
  - Relatively uncommon, mostly mosquito control but some interior (building) uses
  - Some aerosol and foggers called ULV

• Spinning cage, disc and cup

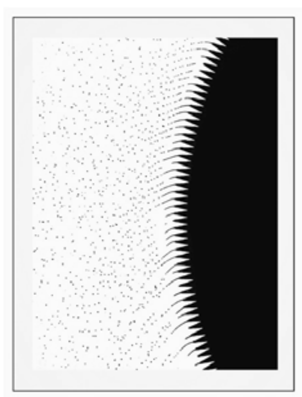
- Insecticide expelled by spinning metal gauze cage, disc or cup, using centrifugal rather than hydraulic force

- Produce narrower range of droplet sizes

- Narrow range of droplet sizes can work against you if not adjusted properly for conditions, requiring more knowledge than with hydraulic applicators



Graphical representation of droplets being formed by spinning disc applicator. Note relatively uniform size of droplets.



- Electrostatic sprayers
  - Apply charge to droplets, encouraging attachment of droplets to target
  - Small droplets more likely to attach, rather than floating away
  - Requires specific oil formulations and canopy coverage is difficult, so not often used

- Pressurized aerosol sprayers
  - Propellant in pressurized can expels liquid
  - Used for local treatment
  - Small droplets subject to drift

Types of sprayers

Solids

- Dusts

- Applied with simple applicator such as mesh bag, or with mechanical bellows/blower

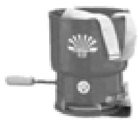
- Prone to drift, but penetration/coverage is good in dense vegetation

- Sometimes used to coat seeds

Some types of dust applicators. The one at top is a simple bellows applicator. The one at bottom is a self applicator that depends on the back-rubbing behavior of cattle to disperse the dust.

Dusting animal burrows, though labor intensive and time consuming, is often the best way to suppress the flea population and prevent plague problems in both animal and human populations.

- Granules
  - Applied by hand or with mechanical distributor
  - Whirlybird sprayers scatter granules
  - Hopper applicators drop granules into or onto soil, often in conjunction with planting seeds



Whirlybird (left) and tractor-driven (right) hopper granule applicators

Other forms of application

Smokes

Insecticide distributed by burning of insecticide-impregnated material
Mostly used indoors for rooms, or in greenhouses
Pyrethrum or pyrethroids popular toxicant

Smokes are normally shaken (above) and then a wick is lit (below), allowing the applicator to leave the site before the insecticide is ignited.

- Fumigation
  - Highly volatile material, usually very toxic
  - Usually applied as a liquid under plastic or in closed environment, then volatilizes
  - Used to sterilize bulk or stored material and soil
  - Expensive and dangerous

Building covered with tarp that is undergoing fumigation

In some areas, such as Florida and California, extensive acreage is cultivated using plastic mulch (below), and fumigants are injected for weed, pathogen, nematode, and insect control.

For small-scale use, fumigant is impregnated in a plastic releaser (right) that can be hung in closets, porches and garages for persistent insect knock-down. They also can be used to keep trash pails fly-free.

- Animal treatments
  - Often pour-on, spot-on, spray-on and dip
  - toxicant sometimes absorbed through skin, often passes into blood and distributed through body
  - spot-on now common for pets, pour-on for larger animals

Dipping of cattle.

- dipping (immersion) is more complete treatment, and less likely to require systemic insecticide because better coverage

In a cattle dip, animals are forced to swim in an insecticide bath.

- Self-application
  - Animals like to rub themselves, so they can be self-treated with dust bags.

Animals can also be induced to enter self-sprays, often when seeking water, food, or moving between pastures.

Ear tags and flea collars release insecticide from a controlled release substrate. The insecticide is redistributed on the animal as it moves and grooms.

Distribution of insecticide-treated cotton in areas where rodents will collect and use it for nest-building is a good way to to get insecticide into rodent burrows where it can kill plague-transmitting fleas and Colorado tick fever-transmitting ticks.

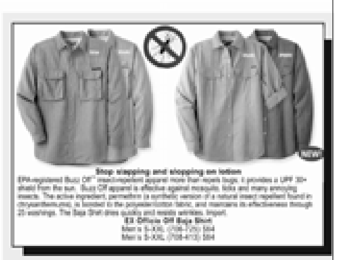
- Another use for controlled release applicator

Permethrin insecticide (which also has repellent properties) is sheltered in the “cap” of this ant guard, and slowly released from a plastic dispenser, providing a barrier to protect the sugar solution from foraging ants.

Treated clothing and mesh vests

Clothing can be impregnated with insecticide, usually pyrethroids (repellency and well as insecticidal), to reduce nuisance effects and disease transmission by biting flies.

At left is an advertisement for pyrethroid-treated clothing designed for outdoor recreation, but it is also used for military uniforms.

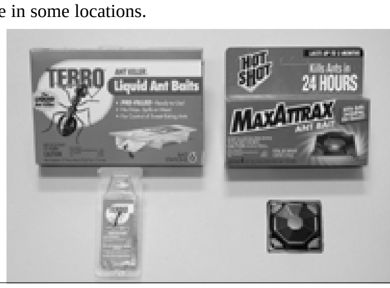


- Baits
  - Insecticide may be incorporated into solid, gel, and liquid food-based baits to provide more selective control. (is selectivity always desirable?)
  - Bait must reflect food habits of pest to be effective, and toxicant must not be repellent.
  - Baits are sometimes sprayed (liquids) or scattered broadly (solids) by hand, machine or aircraft; at other times placed selectively.
  - For social insects, delayed mortality is desirable.
  - Some baits are relatively simple, others more complex: e.g., grains and vegetables, sugars, multiple components.

Pelleted bait (below) and bait applicators (right).

The diversity of bait formulations reflects the diverse biologies of pests. Among the most popular currently are wood-baited termite control systems (the green plastic cylinder below) which are buried in the soil, gel baits for cockroaches that are applied to cryptic areas frequented by cockroaches, and ant baits.

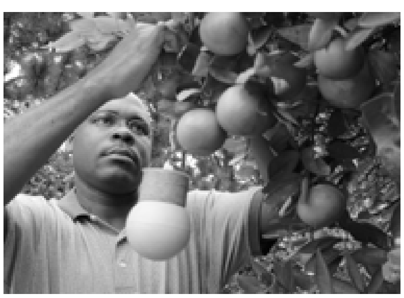
Baits are widely used for household pests because they are a relatively safe, convenient, and effective way to disperse insecticides. Ant baits work best when the feeding habits of the ants align with the bait; both protein (solid) and sugar (liquid) preferring ants occur. Gel baits have become very popular for cockroaches, though a tendency to avoidance of the agar gelling agent among some populations has led to behavioral resistance in some locations.



Tephritid fruit flies and some other insects can be poisoned with sugar solutions containing insecticide that are sprayed onto feeding and resting areas.

- Targets
  - Visual or odor-based stimuli used to attract insect to site where they contact insecticide.
  - Best-known example involves tsetse flies, but colored spheres are used for tephritid fruit flies and rope wicks for house flies.

Insecticide treated tsetse fly trap (left) and trap trampled by elephant (right) - a unique cause for suppression failure!



Hanging a grapefruit model for Caribbean fruit fly control. The brown collar secretes insecticide-containing sugar solution onto the surface, stimulating the fly to feed and ingest a lethal dose.

- Treatment of resting spots
  - Some insects have favorite resting spots that can be selectively treated with residual materials, e.g.
    - walls of homes for mosquitoes
    - beneath sinks and in cracks and crevices for cockroaches
    - eaves of dairy barns for flies
    - trunk of trees for gypsy moth larvae and elm bark beetles
    - along trails for ticks
    - where animals rest for fleas

- Treatment of aquatic habitats
  - Temporary pools and vegetated impoundments for mosquitoes.
  - Rivers and streams for blackflies (West Africa and onchocerciasis).

Rational application of insecticides

- Timing of insecticide application
  - Optimal time to control pest is principal variable
  - Other considerations are:
    - Pest density
    - Weather
    - Work schedule
    - Time of day (wind, pollinators)
    - Natural enemies

Rational application of insecticides, continued

- Dosage and persistence
  - Apply only amount needed (often less than manufacturer suggests).
  - Use less persistent or more selective material to minimize effects on beneficials/pollinators, and resistance.
- Selective placement
  - Optimize effectiveness by understanding insect biology/behavior.
  - Place insecticide where contact is maximized.

Questions

- Can you explain how insecticide droplet technology (particularly droplet size) affects insect control?
- What types of applicators are used to apply liquid insecticides? Solid insecticides?
- Can you distinguish between mistblower and hydraulic sprayers?
- How are animals treated for insect control?
- How does insect control using baits compare to insect control using targets?
- How does timing of application, dosage and persistence, and placement affect control?

Questions from supplementary readings

- Reading 7, Insecticide application: dose transfer
  - What is the importance of “sheet disintegration”?
  - What forces affect the size of a droplet?
  - How does droplet size relate to drift potential? Canopy penetration? Adhesion beneath the leaf?
  - What roles do adjuvants play in drop size and impact?
  - How does the physical surface of a plant affect droplet impaction and retention?
  - How does insect feeding behavior affect contact with insecticide on plant foliage?

More questions from supplementary readings

- Reading 14, temperature and insecticide
  - What is the nature of damage caused by grasshoppers in leafy green crops?
  - How does temperature affect insecticide efficacy?
  - How did temperature affect Beauveria bassiana? esfenvalerate? spinosad?
  - How does hopper mortality compare between plots with plants AND hoppers treated, versus plots with ONLY plants (not hoppers) treated? What does this mean for hopper control when hoppers move from weeds to crop fields?