CHAPTER 4

Pesticide Formulations

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Describe what a pesticide formulation is.
- Explain why pesticides are formulated for end use.
- Distinguish between active and inert ingredients.
- State the meaning of abbreviations used for common types of formulations (e.g., WP).
- List the factors to consider when choosing a formulation for a specific site or situation.
- Discuss the properties of common formulations.
- Evaluate the advantages and disadvantages of the formulations described in this chapter.
- Explain the roles of adjuvants.

A pesticide **formulation** is a combination of active and inert ingredients that forms an end-use pesticide product. Pesticides are formulated to make them safer or easier to use. This is because many pesticide **active ingredients**, in "pure" (technical grade) form, are not suitable for application. In their concentrated form, some are extremely toxic, many do not mix well with water, some are unstable, and some are difficult (or unsafe) to handle, transport, or store. To address these problems, manufacturers add **inert ingredients** to end-use pesticide products. Inert ingredients have no pesticidal activity, and some simply serve as **diluents** or **carriers**. In many cases, inert ingredients make the formulated product safer, easier to handle and apply, and/or more effective.

So, in addition to the active ingredient intended to control the target pest, a formulated product may consist of:

- A carrier or diluent, such as an organic solvent of mineral clay.
- Surface-active ingredients, such as stickers and spreaders.
- Other additives, such as stabilizers, dyes, and chemicals, which make the product safer or enhance pesticidal activity.

FORMULATIONS: AN OVERVIEW

The active ingredients in pesticide products come from many sources. Some, such as azadirachtin, pyrethrum, and rotenone, are extracted from plants. Others are derived from microbes or insects (e.g., *Bacillus thuringiensis* and insect growth regulators). Still others have a mineral origin (e.g., copper and sulfur). However, the vast majority of active ingredients used today are produced in laboratories. These synthetic active ingredients may have been designed by a chemist or discovered through screening processes by examining chemicals generated by various industries or found in nature.

Regardless of where they come from or how they are produced, pesticide active ingredients vary considerably in their physical and chemical properties. One variable is solubility. Some dissolve in water, but many do not. Some are soluble in oils or organic solvents. However, many such solvents are not available to applicators or safe to use. A few active ingredients do not dissolve readily in any **solvent**. Solubility and the intended use of the pesticide are two factors that determine how an active ingredient is formulated (i.e., made into an end-use product).

Liquid pesticide products are usually one of the following:

- A solution.
- A suspension.
- An emulsion.

A **solution** is made by dissolving a substance in a liquid. A true solution is a mixture, but it cannot be separated by filtration or other mechanical means. Once made, a true solution will not "settle out" and does not need shaking or stirring (**agitation**) to keep the mixed components in solution. Solutions are transparent: they will allow light to pass through them. (However, this may not be obvious if one or more components of the mixture are dark in color and the solution is very concentrated.) Sweetened iced tea and saltwater are examples of solutions.

A **suspension** is also a liquid mixture. However, a suspension is formed by dispersing fine (very small), solid particles in a liquid. These solid particles do not dissolve in the liquid carrier. Suspensions must be agitated to maintain uniform particle distribution. Otherwise, the undissolved parts of suspension mixtures will settle (or float to the top). Most suspensions are cloudy or opaque: they will not allow light to pass through them. Pesticide products formulated as suspensions are not water-soluble; they form more dilute suspensions when mixed with water to make a finished spray. Label directions for suspension formulations will instruct you to shake well before measuring and mixing. The label will further state to apply these products only with spray equipment that has enough agitation to keep the final mixture evenly distributed in the spray tank during application. A mixture of flour and water is an example of a suspension.

An **emulsion** is a special kind of suspension: a mixture made by suspending droplets of one liquid in another. Each ingredient retains its unique properties and identity. To make an emulsion, an active ingredient is dissolved in an oil-based solvent and then further diluted with water. Some agitation may be necessary to keep an emulsion from separating. However, most emulsion pesticide product formulations have additives (**emulsifiers** or emulsifying agents) that prevent the product from settling. As a rule, emulsions have a "milky" appearance. An emulsifiable concentrate (E or EC) is an emulsion. Homogenized milk is an example of an emulsion.

Most dry products are made by adhering the active ingredient to some solid carrier, such as talc, clay, silica (the mineral quartz), or plant residues (e.g., ground corncobs).

Some pesticide products are sold in concentrate form and must be mixed or diluted before use. **Concentrates** come in both liquid and solid form. An emul-

sifiable concentrate is an example of a liquid concentrate (LC). Wettable powders (WP), soluble powders (SP), and water-dispersible granules/dry flowables (WDG/DF) are examples of concentrated materials sold in solid form.

Other formulations are sold ready-to-use. You can apply ready-to-use products with no further dilution or mixing. Examples include liquids prepared as end-use dilutions and aerosol (A), dust (D), pellet (P), granule (G), and most bait (B) formulation products. Manufacturers package many specialized pesticides, including products intended for residential uses by non-occupational users, in ready-to-use formulations.

Concentrates are often less expensive per treatment/unit area treated than ready-to-use formulations. However, this cost savings may be offset by other considerations. For example, concentrates are usually more toxic than dilute formulations of the same active ingredient. More handling is required to mix and load them. As a result, concentrates present a higher exposure risk to the user.

Abbreviations in trade or brand names are often used to describe the formulation (e.g., WP for wettable powders), how the pesticide is used (e.g., TC for termiticide concentrate), or the characteristics of the formulation (e.g., LO for a low-odor formulation). The amount of active ingredient (a.i.) and the kind of formulation are listed on the product label. Numbers in a product's trade or brand name may also indicate the amount of active ingredient it contains. For example, 80 WDG indicates that this dry product contains 80% by weight of active ingredient and is a water-dispersible granule. In this case, a 10-pound bag of product contains 8 pounds of a.i. and 2 pounds of inert ingredient. Liquid formulations usually state the amount of a.i. in pounds per gallon. For example, 4F means 4 pounds of the a.i. per gallon in a flowable formulation. Some common formulation abbreviations are listed in Table 4.1.

A single active ingredient is often sold in several kinds of formulations. Below is a short description of common formulations, along with the pros and cons of each. If more than one formu-

Table 4.1 Abbreviations for Common Formulations

A	=	Aerosol
AF	=	Aqueous flowable
B	=	Bait
C	=	Concentrate
D	=	Dust
DF	=	Dry flowables (see WDG)
E	=	Emulsifiable concentrate
EC	=	Emulsifiable concentrate
F	=	Flowable
G	=	Granules
GL	=	Gel
L	=	Liquid
LC	=	Liquid concentrate
LV	=	Low volatile
M	=	Microencapsulated
P	=	Pellets
PS	=	Pellets
RTU	=	Ready-to-use
S	=	Solution
SP	=	Soluble powder (*or* soluble packet; see WSP)
ULV	=	Ultra-low volume
W	=	Wettable powder
WDG	=	Water-dispersible granules (see DF)
WP	=	Wettable powder
WS	=	Water soluble
WSB	=	Water-soluble bag (see WSP: water-soluble packet)
WSC	=	Water-soluble concentrate
WSL	=	Water-soluble liquid
WSP	=	Water-soluble powder (*or* water-soluble packet; see WSB)

lation is available for your pest control site and situation, choose the best one for the job. Base your decision on:

- Legal, labeled uses.
- The signal word.
- Applicator safety.
- Environmental safety.
- Pest biology.
- Site characteristics.
- Target (surface to be treated).
- Appropriate and available application equipment.

Ask yourself these questions:

- Is the intended use listed on the product label?
- Do I have the necessary application equipment?
- Can the formulation be applied appropriately under the conditions in the application area?
- Will the formulation reach the intended target and stay in place long enough to control the pest?
- Is the formulation likely to damage the surface?
- Could I choose a less hazardous formulation that would still be as effective?

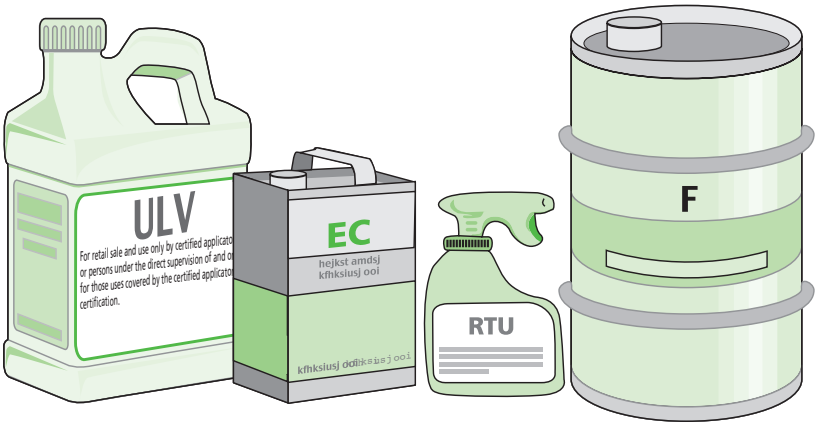
Cost is always a consideration, but pesticide and pest management concerns should come first.

LIQUID FORMULATIONS

Most liquid formulations are diluted with water to make a finished spray. However, some labels direct users to mix the product with another solvent such as crop oil or other light oil as a carrier.

Emulsifiable Concentrates (E or EC)

An emulsifiable concentrate formulation usually contains an oil-soluble liquid active ingredient, one or more petroleum-based solvents, and a mixing agent. The mixing agent allows the formulation to be mixed with water to form an emulsion. Most ECs contain between 2 and 6 pounds of active ingredient per gallon. ECs are among the most versatile formulations. They are used against pests in agricultural, ornamental and turf, forestry, structural, food processing, livestock, and public health settings. ECs are adaptable to many types of application equipment, from small, portable sprayers to hydraulic sprayers, low-volume ground sprayers, mist blowers, and low-volume aircraft sprayers.



Advantages:

- Relatively easy to handle, transport, and store.
- Easy to pour and measure.
- Little agitation required; will not settle out or separate when equipment is running.
- Not abrasive; does not cause excessive equipment wear.
- Will not usually plug screens or nozzles.
- Leave little visible residue on treated surfaces.

Disadvantages:

- High concentration of active ingredient(s) makes it easy to overdose or underdose through mixing or calibration errors.

- May damage treated plants or surfaces (petroleum-based solvents or overdosing may cause **phytotoxicity**).
- Easily absorbed through skin of humans or animals.
- Splashes and spills are relatively difficult to clean up and/or decontaminate.
- Many have a strong odor.
- Solvents may cause equipment "wear and tear." For example, rubber or plastic hoses, gaskets, pump parts, and other exposed surfaces may deteriorate.
- May cause pitting or discoloration of painted finishes or other treated surfaces.
- Flammable; should be used and stored away from heat or open flame.
- May be corrosive.

Solutions (S)

Some pesticide active ingredients dissolve readily in a liquid solvent, such as water or a petroleum-based diluent. When mixed, they form a solution that does not settle out or separate. Formulations of these pesticides usually contain the active ingredient, solvent (carrier or diluent), and one or more other ingredients. Solutions are suitable for any type of sprayer, indoors or outdoors. Consequently, they are registered for many sites, including structural, institutional, public health, and household pest control; livestock and poultry pest management; space sprays in barns and warehouses; and treatment of food and fiber crops, turf, and ornamental plants.

Ready-to-Use (RTU) Low-Concentrate Solutions

Ready-to-use formulations require no further dilution before application. They consist of a small amount of active ingredient (often 1% or less per unit volume). Some ready-to-use products contain petroleum-based solvents; others are water-based. Many RTU products are produced for pest management professionals (who treat structural and institutional pests) and for nonoccupational users.

Advantages:

- Convenient; neither measuring nor mixing is required.
- Some are packaged and sold in—or with—an application device. If this is the case, no loading is required.
- Less personal exposure risk due to reduced toxicity and handling.

Disadvantages:

- Limited availability.
- High cost per unit of active ingredient.

The time saved and convenience of using RTU products may outweigh the product cost.

Concentrate Solutions (C, LC, or WSC/WSL)

Other solutions are available as concentrates that require dilution with a liquid solvent before you apply them. Often the solvent is water, but it may also be a refined oil or petroleum-based solvent. When diluted with the label-specified carrier, these formulations form true solutions.

Advantages:

- Relatively easy to handle, transport, and store; easy to pour and measure.
- No agitation necessary.
- Not abrasive; do not cause excessive equipment wear.
- Do not plug screens or nozzles.
- Do not usually leave visible residues on treated surfaces.

Disadvantages:

- Limited availability, especially water-based solutions.
- Spills and splashes may be difficult to clean up and/or decontaminate.

- Some are easily absorbed through skin of humans or animals.

The other benefits and drawbacks of concentrated solutions vary. They depend on the concentration of active ingredient, solvent or diluent used, application site, and application equipment.

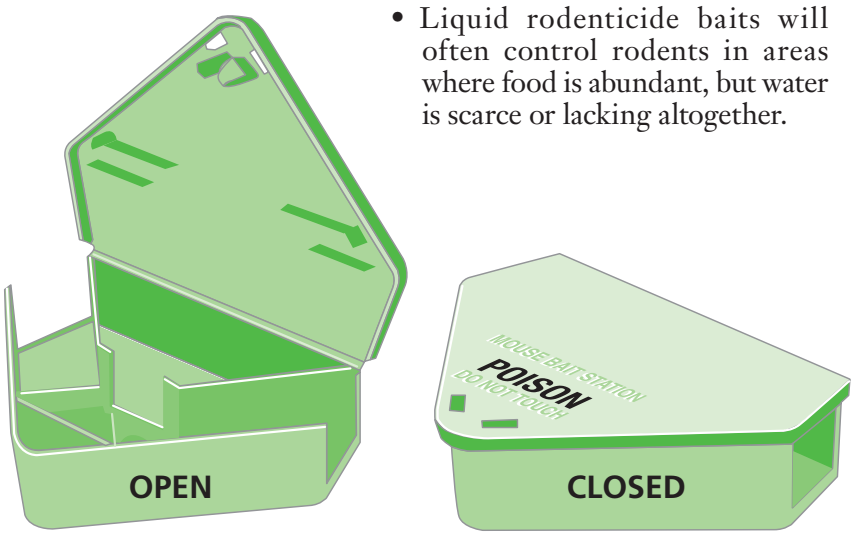
Liquid Baits

Some insecticides and rodenticides are now formulated as liquid baits. Most liquid insecticides are concentrated sugar solutions. They are packaged in ready-to-use bait stations to kill ants and cockroaches.

As a rule, liquid rodenticide baits are mixed with water and placed in specially designed bait stations. They are useful in sites where sanitation is poor because traditional food-based baits "compete" with other food sources. As is the case with solid baits, you must place bait stations in safe, strategic locations while following label directions and taking care to protect children and nontarget organisms.

Advantages:

- Liquid ant baits are very useful in controlling sugar-feeding ants.
- Ants that will feed on liquid baits carry this material to the colony.
- Liquid rodenticide baits will often control rodents in areas where food is abundant, but water is scarce or lacking altogether.



A bait station used in rodent control in the closed and open positions. Bait formulations are placed inside the tamper-resistant station.

Disadvantages:

- Not all ants, cockroaches, and rodents will feed on liquid baits.
- You must refill or replace liquid-containing bait stations frequently.

For information about solid-formulation baits, refer to "Baits" in the "Dry or Solid Formulations" section.

Ultra-Low Volume

Ultra-low-volume concentrates have almost 100% active ingredient. They are designed to be used "as is" or diluted with only small quantities of specified solvents. These special-purpose formulations are most suitable for outdoor applications, such as in agricultural, forestry, ornamental, and mosquito control programs. ULV products are applied as very fine droplets at very low rates per unit area (or volume).

Advantages:

- Relatively easy to handle, transport, and store.
- Little or no agitation required.
- Not abrasive to equipment.
- Do not plug screens and nozzles.
- Leave little visible residue on treated surfaces.

Disadvantages:

- High drift hazard due to small droplet size.
- Specialized equipment required.
- Easily absorbed through skin of humans or animals; high dermal and inhalation exposure risk (concentrated product applied as fine droplets).
- Products and/or solvents may cause rubber or plastic hoses, gaskets, and pump parts and other surfaces to deteriorate.
- Calibration and application must be performed with special care because ULV products are applied in concentrated form.

Invert Emulsions

Invert emulsions contain a water-soluble pesticide dispersed in an oil carrier. These products require a special kind of emulsifier that allows the pesticide to be mixed with a large volume of petroleum-based carrier, usually fuel oil. Invert emulsions are less susceptible to drift because oil evaporates more slowly than water. When applied on a hot, dry day, a water-based droplet will become smaller as the water portion of the droplet evaporates. Invert emulsion droplets do not "shrink" as rapidly when applied in the same weather conditions. This means less drift and more pesticide on target. Invert emulsions are thick mixtures, with the consistency of mayonnaise. In addition, invert emulsions are applied as very large droplets, which reduce drift.

The oil phase of this kind of formulation also serves as a sticker-spreader. This quality improves rainfast properties and surface coverage. It also increases **absorption** and/or penetration. This, in turn, reduces loss due to runoff. Invert emulsions are relatively uncommon. They are most often used in weed control on rights-of-way to reduce the chance of drift to susceptible nontarget plants or sensitive areas.

Advantages:

- Low drift.
- Increased rate of penetration and/or absorption.
- Increased rainfastness and reduced runoff.

Disadvantages:

- Difficult to treat the underside of foliage or other targets because droplets are large and heavy.
- Limited availability.

Flowables (F or AF)

Some active ingredients are insoluble solids: substances that will not dissolve in either water or oil. These may be formulated as flowables. (Most manufacturers use the letter "F" by the trade name to designate that the formulation is a flowable. However, some use the letter "L," meaning that an insoluble material is presented in "liquid" form.) Most flowables are prepared by first impregnating them onto a dry carrier, such as clay. Then, the active ingredient plus carrier (or the active ingredient alone) are ground into a fine powder. Next, the fine powder is suspended in a very small amount of liquid (and perhaps other inert ingredients). The resulting product is a thick liquid suspension.

Flowables combine many of the characteristics of liquid emulsifiable concentrates and dry wettable powders. They appear in the "Liquid Formulations" section because the end-use product is a thick liquid. Flowables are often used for the same types of pest control operations as ECs.

Advantages:

- Easy to handle and apply; low exposure risk.
- Generally not phytotoxic.
- Seldom clog nozzles.
- Splashes are less likely than with other liquid formulations.

Disdvantages:

- May settle; need shaking before measuring and mixing.
- Difficult to remove all of product from the container. Containers may be difficult to rinse.
- Require moderate agitation.
- May be **abrasive**; contribute to "wear and tear" of spray application equipment.
- Spills may be harder to clean up.
- May leave a visible residue on treated surfaces.

Aerosols (A)

Aerosol formulations contain one or more active ingredients and a solvent. Most aerosols contain a low percentage of active ingredient. There are two types of aerosol formulations:

- The ready-to-use type (often sold in pressurized sealed containers that serve as application devices).
- Those made for use in electric or gasoline-powered aerosol generators that release the formulated product as a smoke or fog.

Ready-to-Use Aerosols

Ready-to-use aerosol formulations are usually small, self-contained units that release pesticide when the nozzle valve is triggered. An inert pressurized gas pushes the pesticide through a fine opening when the gas is released, creating fine droplets. These products are effective in greenhouses, in small areas inside buildings, or in localized outdoor areas. Commercial models, which hold 5 to 10 pounds of pesticide, are usually refillable.

Advantages:

- Easy to use; convenient.
- Portable.
- Easily stored.
- Convenient way to buy and apply a small amount of pesticide.
- Retain potency for some time.

Disadvantages:

- Practical for only a few limited or specialized uses.
- Risk of inhalation exposure.
- Hazardous if punctured, overheated, or used near an open flame.
- May be difficult to direct material released to a single target site or pest.

Formulations for Smoke or Fog Generators

Formulations for smoke or fog generators are not packaged and sold under pressure. They are used in machines that break the liquid formulation into a fine mist or fog (aerosol). Using a rapidly whirling disk or heated surface, the machines produce and distribute very fine droplets. These formulations are used mainly for insect control in structures such as greenhouses, barns, and warehouses and for outdoor mosquito and biting fly control.

Advantages:

- Easy way to fill an entire space with pesticide.

Disadvantages:

- Highly specialized use sites and equipment.
- Difficult to confine to target site or pest.
- Spills and splashes may be difficult to clean up and/or decontaminate.
- May require respiratory protection to prevent inhalation exposure.

DRY OR SOLID FORMULATIONS

There are two general types of dry formulations. Some are ready-to-use. Others are concentrates, which must be mixed with water and applied as a spray.

Dusts (D)

Most dust formulations are ready-to-use and contain a low percentage of active ingredient (usually 10% or less by weight). A few dust formulations, however, are concentrates and contain

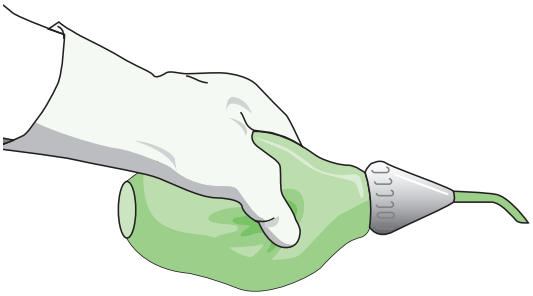
a much higher percentage of active ingredient. These concentrates must be mixed with dry inert carriers before application.

Dusts have one or more active ingredients plus a very fine, dry inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash. The size of individual dust particles varies, but all are quite small. Due to their small size, dusts need careful handling to prevent nontarget exposure, including drift. They are not water-soluble. Therefore, do not mix them with a liquid solvent.

Dusts are always used dry. They are often used as seed treatments and in some other agricultural operations. Some ornamental and garden pest management products aimed at homeowners are dust formulations. In structures, dust formulations are useful to treat cracks and crevices and for spot treatments to control insect pests. Dusts are also a good tool to control lice, fleas, and other external parasites on pets and livestock.

Special dusts known as tracking powders are effective for insect and rodent monitoring and control. These products are finely ground dusts with an adsorbed stomach poison. Insects and rodents walk through the dust, pick it up on their legs and bodies or feet and fur, and ingest the poisonous dust when grooming. Tracking powders are effective in sites and situations where bait acceptance is poor (for example, where food is abundant).

NOTE: *Another option is to use a nontoxic powder, such as talc or flour, to monitor and track rodent activity in buildings.*



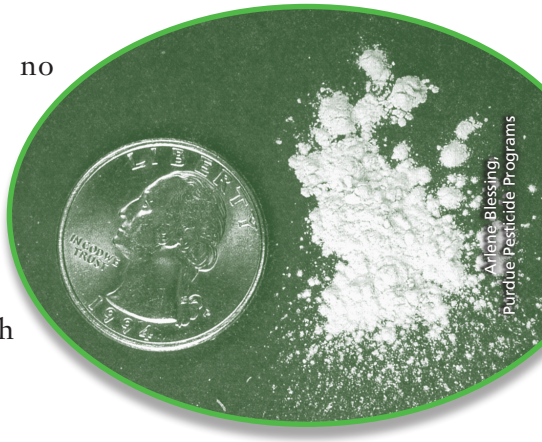
A bulb duster used for applying dust formulations to cracks, crevices, and voids in buildings.

Advantages:

- Usually ready-to-use; no mixing.
- A good alternative where moisture from a spray might cause damage.
- Applied with simple application equipment.
- Effective in hard-to-reach indoor areas.

Disadvantages:

- Easily drift off target during application.
- Residues do not adhere to treated surfaces, including foliage, as well as liquids do; may easily wash off or blow away.
- May irritate eyes, nose, throat, and skin; pose a relatively high inhalation exposure risk to handlers.
- Dampness may cause product to clump and equipment to clog; difficult to apply in damp or humid environments.
- Some kinds of application equipment and devices are hard to calibrate.
- Difficult to get an even distribution of particles.

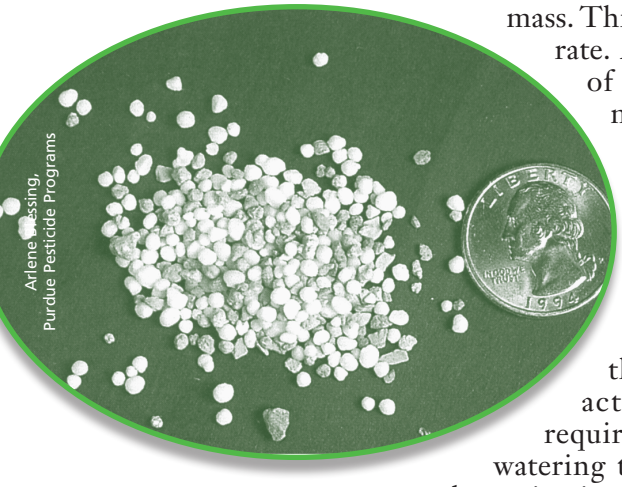


Dust formulations are always used dry.

Granules (G)

Granular formulations are similar to dust formulations; however, granular particles are larger and heavier. Like dusts, they are not water-soluble. They are ready-to-use–not intended to be mixed with water and applied as a liquid suspension. The coarse particles that serve as carriers for granular formulations are adsorptive substances like clay or absorptive plant material such as ground corncobs or walnut shells. The active ingredient either coats the outside of the granules or is absorbed into them. The amount of active ingredient is relatively low, usually ranging from 1% to 15%.

Because many granular formulations use carriers that absorb moisture, humidity will affect particle size and



Granular formulations are larger and heavier than dust formulations.

mass. This, in turn, will affect flow rate. Also, different "batches" of the same formulation may differ slightly in size or shape and density. For these reasons, you must calibrate granular application devices often.

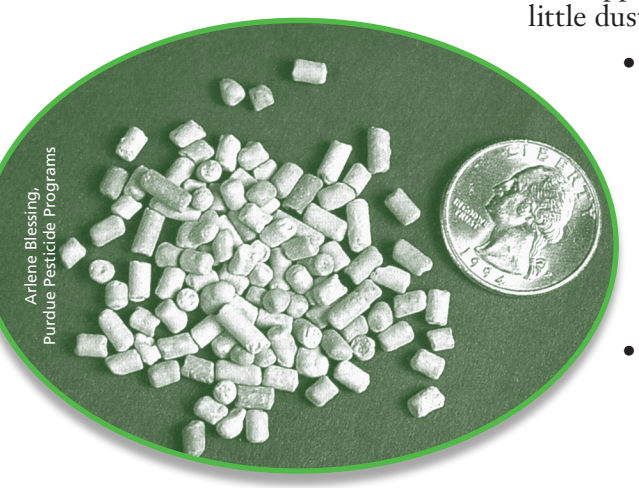
Once applied, granules slowly release the adsorbed or absorbed active ingredient. Some require soil moisture, rain, or watering to initiate the release of the active ingredient. Other granules do so as they decompose.

Granular pesticides are mostly used to apply chemicals to the soil, where they control weeds, nematodes, and insects or are absorbed by plant roots. Most granular formulations are used to deliver systemic pesticides. Granules are a common choice in many sites and situations.

Aerial applicators sometimes use granular formulations to reduce drift or penetrate dense vegetation. Granular formulations are also useful in aquatic situations to control mosquito larvae and aquatic weeds.

Advantages:

- Ready-to-use; no mixing.
- Drift hazard is low, and particles settle quickly.
- Low applicator hazard: no spray; little dust.
- Weight carries the formulation through foliage to soil or water target.
- Applied with simple application equipment, such as seeders or fertilizer spreaders.
- May break down more slowly than WPs or ECs because of a slow-release coating.



In pellet formulations, all particles are the same weight and shape.

Disadvantages:

- Application equipment needs frequent calibration.
- Application equipment is not as convenient to calibrate as spray equipment. Released particles are measured by weight instead of by volume.
- Uniform application may be difficult with some devices (e.g., rotary spreaders).
- Granules do not stick to foliage or other uneven surfaces. For this reason, contact products are rarely formulated this way.
- May need to be incorporated into soil or planting medium.
- May need moisture to release the active ingredient; may not be effective in drought conditions.
- May be hazardous to nontarget species, especially waterfowl and other birds. This is because birds may feed on grain- or seed-like granules or mistake them for "grit" they need to grind up their food.
- Bulky; low percentage of active ingredient per unit volume.

Pellets (P or PS)

Most pellet formulations are very similar to granular formulations in their uses, advantages, and disadvantages. However, in pellet formulations, all the particles are more or less the same weight and shape. They are produced by combining the active ingredient with inert materials to form a "slurry"—a thick liquid mixture. This mixture is then extruded under pressure. As a result, pellets are round in cross section and cut to a specific length. Because pellet particles are more uniform, you can apply them with precision. However, in many cases, pellets are applied as spot treatments. A few fumigants are formulated as pellets and are clearly labeled as such to avoid confusing them with nonfumigant pellets.

Wettable Powders (WP or W)

Wettable powders are dry, finely ground solid materials. Most include wetting and/or dispersing agents. Usually, they must be mixed with water

and applied as a spray. A few products, however, may be applied dry or as a liquid suspension.

Wettable powders contain 5% to 95% active ingredient—usually 50% or more. Wettable powder particles do not dissolve in water. When mixed with water, they form a suspension. They will settle out quickly without constant agitation to keep them suspended.

To prepare a spray suspension, you must form a slurry. Mix a WP with a small amount of water, and then dilute this slurry mixture further.

Wettable powders are effective for most pest problems and in most types of spray equipment where agitation is possible. They have excellent residual activity and do not usually harm treated surfaces. When you apply a WP spray suspension to a target, most of the pesticide remains on the surface. This is true even for porous materials, such as concrete, plaster, and untreated wood. In such cases, only the water carrier penetrates the porous material. Wettable powder particles remain on the treated surface.

Advantages:

- Easy to store, transport, and handle.
- Less likely than ECs and other petroleum-based formulations to harm treated plants, animals, and surfaces.
- As a rule, not phytotoxic.
- Less risk of skin and eye absorption than ECs and other liquid formulations.

Disadvantages:

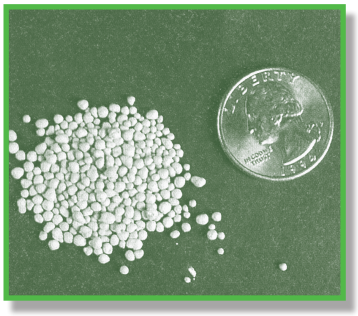
- Not easy to measure; must be weighed.
- Not easy to mix.
- Inhalation hazard to applicator while measuring and mixing the concentrated powder.
- Suspended particles require good and constant agitation (usually mechanical) in the spray tank and quickly settle out if agitation ceases.
- Abrasive to pumps and nozzles; cause equipment wear.
- Difficult to mix in very hard or very alkaline water.
- If not mixed properly, may clog nozzles and screens.
- Residues may be visible on treated surfaces.

Wettable powders are dry, finely ground formulations that look like dusts.

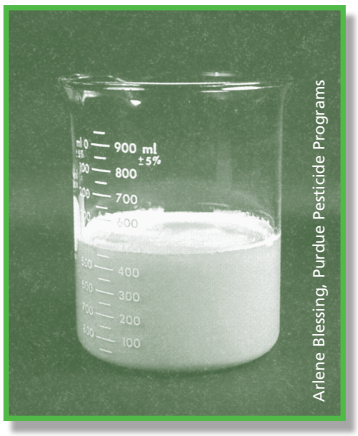
Water-Dispersible Granules (WDG) or Dry Flowables (DF)

Water-dispersible granular formulations are wettable powder formulations compressed into dust-free, granule-sized particles. Most come with a product-specific measuring device, with dry ounce (or pound) increment marks based on product density (weight per unit volume). Because of this and the fact that they readily flow or pour out of their containers, they are easier to measure and cleaner to handle than WPs. Like wettable powders, water-dispersible granules are mixed with water and applied as a spray suspension. Once in water, the granules break apart into fine powder. The formulation requires constant agitation to keep it suspended in water. Water-dispersible granules share the advantages and disadvantages of wettable powders. However, WDGs have one added benefit: reduced handler exposure risk. This is because WDGs/DFs are:

- Made of larger, less "dusty" particles.
- Easier to remove from their container and measure.



Water-dispersible granule before mixing.



Water-dispersible granule after mixing.

Soluble Powders (SP or WSP)

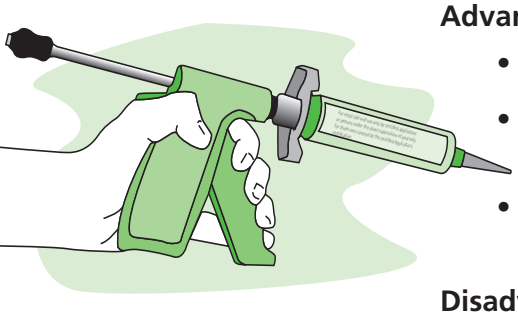
Soluble powder formulations look like wettable powders. However, when mixed with water, soluble powders dissolve readily in water and form a true solution. After a thorough mixing, no additional agitation is necessary. The amount of active ingredient in soluble

powders ranges from 15% to 95%; it usually is more than 50%. Soluble powders have all the advantages of WPs but only one of the disadvantages: inhalation hazard during mixing. Not many pesticides are available in this formulation because very few active ingredients dissolve in water.

Baits (B)

A bait formulation is an active ingredient mixed with food or another attractive substance. The bait either attracts the pests or is placed where the pests will find it. Many baits are solid (blocks, granules, or pellets), but some are liquids, pastes, or gels. The amount of active ingredient in most bait formulations is quite low, usually less than 5%.

Baits are used inside buildings to control ants, cockroaches, flies, and other insects. Outdoors, they can control vertebrate pests, such as rodents, other mammals, and birds as well as snails, slugs, and some insects. Applicators must place bait stations in safe, strategic locations while following label directions to protect children and nontarget organisms.



A bait gun used by the pest control industry to treat small cracks and crevices.

Advantages:

- Ready-to-use.
- Entire area need not be covered because pest goes to bait.
- Control pests that move in and out of an area.

Disadvantages:

- May be attractive to children and pets.
- May kill domestic animals and nontarget wildlife.
- Require careful placement and inspection.
- Pest may prefer the crop or other food to the bait.
- Dead vertebrate pests may cause odor problems.
- If baits are not removed after the pesticide stops working, they may serve as a food supply for the target pest or other pests.
- May not work in situations where pests have many other food or water sources.

For information about liquid baits, see “Liquid Formulations” above.

Pastes, Gels, and Other Injectable Baits

Pastes and gel baits are mainly used in the pest control industry for ants and cockroaches. In fact, insecticides formulated as pastes and gels are now the primary formulations used in cockroach control. They are designed to be injected or placed as either a bead or dot inside small cracks and crevices of building elements where insects tend to hide or travel. Two basic types of tools are used to apply pastes and gels: syringes and bait guns. The bait is forced out of the tip of the device by applying pressure to a plunger or trigger.

Advantages:

- Odorless; no vapors.
- Low human toxicity.
- Last for long periods.
- Low applicator exposure risk.
- Hidden placements minimize human and pet exposure.
- Very accurate in their placement and dosage.
- Easily placed where insects shelter for maximum effectiveness.

Disadvantages:

- Can become contaminated from exposure to other pesticides and cleaning products.
- When exposed to high temperatures, gels can run and drip.
- May stain porous surfaces.
- Repeated applications can cause an unsightly buildup.

OTHER FORMULATIONS

This section describes other formulations that:

- Are not easily classified as liquid or dry/solid.
- Are formulated and/or applied as gases.
- Have some special packaging or delivery method.

Fumigants

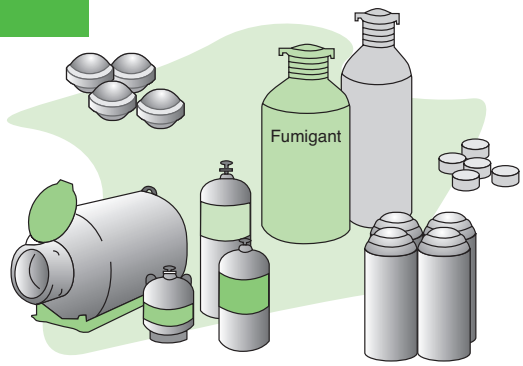
Fumigants are pesticides that deliver the active ingredient to the target site in the form of a gas. Some active ingredients are liquids when packaged under high pressure but become gases when released. Other active ingredients are **volatile** liquids. They may be enclosed in an ordinary container and not packaged under pressure. Still others are solids that release gases after application in humid conditions or in the presence of water or water vapor. Fumigants are used for structural pest control, in food- and grain-storage facilities, and in regulatory pest control at ports of entry and state and national borders. In agricultural pest control, fumigants are effective in soil, greenhouses, and commodity storage areas (such as grain bins).

Advantages:

- Toxic to a wide range of pests.
- Can penetrate cracks, crevices, wood, and tightly packed areas (such as soil or grains).
- A single treatment will usually kill most pests in the treated space.

Disadvantages:

- The target site must be enclosed or covered to prevent the gas from escaping.
- Nonspecific and highly toxic to humans and all other organisms.
- High inhalation exposure risk.
- Most require the use of specialized personal protective equipment.
- May require the use of specialized application equipment.
- Some have specific temperature requirements.



Fumigants are packaged in liquid and solid forms. Both turn into poisonous gases when applied.

Microencapsulated Pesticides (M)

Microencapsulated pesticides are dry particles or liquid droplets surrounded by a coating. Coatings may be plastic, starch, or some other material. Microencapsulated pesticides are mixed with water and applied as a spray. Once applied, the pesticide is released from the capsule. In some situations, the encapsulation process can provide "timed" slow release of the active ingredient. Depending on the physical properties of the coating, release of the pesticide active ingredient may be weather-dependent. If the release is slower than normal (for example, due to dry or cool weather), residues may remain on treated plants or surfaces longer than expected. As a result, some microencapsulated products have relatively long restricted-entry or preharvest intervals.

Some microencapsulated pesticide products contain highly toxic materials with a coating to increase handler safety. Others are microencapsulated for different reasons; for example, to reduce staining or odor or to protect the active ingredient from photodegradation. Highly toxic microencapsulated pesticides may be very hazardous to bees if the particles do not break down quickly and are the same size as pollen grains. Foraging bees may collect them and carry them back to the hive. Later, when the coatings break down and release the pesticide, the colony may be poisoned. Some microencapsulated soil-applied products may be more prone to leaching.

Advantages:

- Coatings help protect the applicator.

- Easy to mix, handle, and apply.
- Timed release of active ingredient prolongs effectiveness (i.e., may result in fewer applications; application timing may be less critical).
- Reduced volatility.
- Reduced odor.
- Less likely to stain or otherwise damage treated surfaces.
- Reduced phytotoxicity.

Disdvantages:

- Constant agitation may be necessary in spray tank (depending on the properties of the coating).
- Risk of injuring or killing bees (if the microencapsulated product is toxic to them).
- Long restricted-entry or preharvest intervals for highly toxic products.

Water-Soluble Packaging (WSB or WSP)

More and more pesticide products are available in water-soluble bags (WSBs). A special film packages a precise amount of wettable powder, soluble powder, or gel containing the pesticide active ingredient(s). When added to water in a spray tank, the bag dissolves and releases the contents, which then are suspended or dissolved. This packaging method reduces handler exposure risk. It also simplifies measuring. However, water-soluble packaging is just that—as a rule, it will not dissolve in organic solvents or undiluted ECs. As a result, mixers and loaders must follow label instructions when preparing a spray mixture. Store water-soluble products in a dry place, and do not handle them with damp or wet gloves.


M.J. Weaver, Virginia Tech Pesticide Programs

Adding water-soluble packet to a spray tank.

Advantages:

- Accurate premeasured unit doses.
- Increased handler safety; greatly reduced exposure risk.
- Lower risk of spills.

Disadvantages:

- Package size may not match volume of prepared solution needed and/or spray tank volume.
- May not be suitable for products applied in pounds or gallons of active ingredient per acre, due to the size or number of packets required.
- Must be kept dry—away from water or high humidity—until ready to use.

Impregnates

Some pesticide products consist of a pesticide active ingredient incorporated into a solid material, usually some kind of plastic. The pesticide evaporates or is released over time, and the vapors control nearby pests. Common examples include:

- Livestock ear tags.
- Plastic pest strips and adhesive tapes.
- Pet collars.

Fertilizers may also be impregnated with pesticides.

Animal Systemics

Animal systemics are absorbed by, enter the tissues of, and move within the treated animal. Usually, these pesticides are applied externally or orally. They can control fleas and other external blood-feeding insects as well as worms and other internal parasites. External application methods include pour-on liquids, sprays, and dusts. Oral applications include food additives and premeasured capsules, pastes, or liquids.

Pesticide-Fertilizer Combinations

Many pesticide products—usually granule and pellet formulations—are

combinations of fertilizers and pesticides. Such products are convenient because they allow the applicator to control pests and apply nutrients at the same time. Some are prepackaged: homeowners commonly use these for their lawns. Dealers or growers may custom mix pesticides with fertilizers to meet specific crop requirements.

PESTICIDE MIXTURES

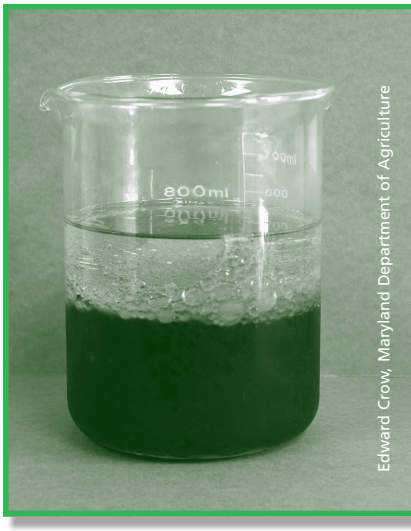
Sometimes, product manufacturers combine pesticides with other pesticides or fertilizers for sale as premixes (see "Pesticide-Fertilizer Combinations" above). However, when premixes are not available (or are not offered in the desired combination), you may combine products at the time of application. **Tank mixing**—combining two or more crop-production products (pesticides and/or fertilizers) and applying them at the same time—is convenient and cost-effective. This practice can save the time, labor, fuel, and equipment wear involved in multiple applications. Tank mixing also reduces soil compaction and the risk of mechanical damage to crops or treated areas. Situations appropriate for tank mixing include combining fungicides and insecticides to treat fruit trees or field crops. Another common example is combining herbicides to increase the number of weed species controlled (control spectrum). However, products must be compatible in order to be tank-mixed.

Federal law allows applicators to combine pesticides unless the labeling of one or more components of the intended tank mix specifically prohibits it. If no prohibitions exist, applicators may mix:

- Pesticide with fertilizer.
- Two or more pesticides.

When pesticides are tank-mixed, all of the dosages must be at or below the label rate for each separate component of the mixture.

For more information about the causes and effects of incompatibility, how to do a compatibility test, and how to prepare a tank mix, see Chapter 10, Planning the Pesticide Application.



Incompatibility is a condition that prevents pesticides from mixing together properly to form a uniform solution or suspension.

ADJUVANTS

An **adjuvant** is a chemical that can affect how a pesticide works. Adjuvants:

- Improve the action of a pesticide.
- Change the characteristics of a pesticide formulation or a spray mixture (suspension or solution).

Most end-use pesticide products, especially those that are applied to foliage, contain adjuvants. However, in some situations, applicators may add them to a tank mix when making a finished spray mixture. Many adjuvants increase effectiveness and/or safety. Although they enhance the action of a pesticide or modify the properties of a spray solution, adjuvants alone have no pesticidal activity. Use them to customize the product or formulation for specific needs or to compensate for local conditions.

Because adjuvants lack pesticidal properties, the U.S. Environmental Protection Agency does not register them. As a result, there are no standards for composition, quality, or performance. If you have questions about an adjuvant, contact the manufacturer. Companies that produce these products can provide labels, technical data sheets, Safety Data Sheets (SDSs), supplemental labeling, and promotional literature.

Before using any adjuvant, consult the pesticide product label. Some products have very specific adjuvant recommendations or prohibitions. If a label instructs you to use an adjuvant, use the type called for at the directed

rate. As noted, many products already contain those adjuvants deemed necessary or useful by the manufacturer or formulator. Adding others may actually decrease efficacy or result in unintended —and possibly undesirable—effects.

Types of Adjuvants

There are many types of adjuvants. Here are some that are commonly used:

- Antifoaming (defoaming) agents —reduce foaming of spray mixtures that may result from using some surfactants and/or from vigorous agitation.
- Buffers or pH modifiers—allow pesticides to be mixed with diluents or other pesticides of different acidity or alkalinity. Most pesticide solutions or suspensions are stable between pH 5.5 and 7.0 (slightly acidic to neutral). Water outside this range may cause pesticides to degrade—very rapidly, in some cases. If you use a buffer, add it to the spray tank water first and mix well. The water must be pH neutral or slightly acidic to start, before adding pesticides or other adjuvants.
- Compatibility agents—help combine pesticides (or pesticides and fertilizers) effectively; reduce or eliminate incompatibility.
- Drift control additives (deposition aids)—reduce drift; increase average droplet size and/or lower the number of "fines" (very small droplets) produced.
- Emulsifiers—allow petroleum-based pesticides (ECs) to mix with water.
- Extenders—keep pesticides active on a target for an extended period. Some adjuvant manufacturers use this name for stickers. (See "Stickers" below.)
- Invert emulsifiers—allow water-based pesticides to mix with petroleum carrier.
- Plant penetrants—allow the pesticide to pass through (penetrate) the outer surface to the inside of treated foliage. Certain plant penetrants may increase penetration on some—but not all—plant species.
- Safeners—reduce the toxicity of a pesticide formulation to the pesticide handler or to the treated surface.
- Spreader—allow pesticide to form a uniform coating layer over the treated surface.
- Stickers—allow pesticide to stay on a treated surface. Some types of stickers increase adhesion of solid particles to a treated surface. This reduces the amount of pesticide that washes off due to rain or irrigation. Others reduce evaporation and/or slow photodegradation. (See "Extenders" above.)
- Surfactant—see "Surfactants" below.
- Thickeners—increase viscosity (thickness) of spray mixtures. Thickeners may reduce drift and/or slow evaporation. (Slowing evaporation is useful when applying systemic pesticides. It increases the time during which the active ingredient can be absorbed by or penetrate plant foliage.)
- Wetting agents—allow wettable powders to mix with water.

TYPES OF ADJUVANTS

Surfactants
- Wetting agents and spreaders

Stickers

Extenders

Plant penetrants

Compatibility agents

Buffers or pH modifiers

Drift retardants

Defoaming agents

Thickeners

Surfactants

Some of the most common adjuvants are **surfactants** (***sur***face ***act***ive ingredie***nts***), which alter the dispersing, spreading, and wetting properties of spray droplets. Examples of surfactants are wetting agents and spreaders. These products physically change the surface tension of a spray droplet. In order to perform well, some pesticide sprays must be able to wet treated foliage thoroughly and evenly. Surfactants that reduce surface tension enable droplets to spread out instead of bead up. This results in better coverage and increases the odds that the pest will contact the

pesticide. Surfactants are particularly helpful when treating plants with waxy or hairy leaves (see Figure 4.1).

Surfactants are classified by how they split apart into charged atoms or molecules, called ions.

- Anionic surfactants have a negative charge. They are most often used with contact pesticides, which control the pest by direct contact instead of being absorbed systemically.
- Cationic surfactants have a positive charge. Do not use them as "stand-alone" surfactants—often, they are phytotoxic.
- Nonionic surfactants have no electrical charge. They are often used with systemic products and help sprays penetrate plant cuticles. They are compatible with most pesticide products.

A pesticide can behave very differently in the presence of an anionic, cationic, or nonionic surfactant. For this reason, you must follow label directions when choosing one of these additives. Selecting the wrong surfactant can reduce efficacy and damage treated plants or surfaces.

The terms used when talking about pesticide additives can be confusing. People sometimes use the words "adjuvant" and "surfactant" interchangeably. However, an adjuvant is ANY substance added to modify properties of a pesticide formulation or finished spray. A surfactant is a specific kind of adjuvant—one that affects the interaction of a spray droplet and a treated surface. All surfactants are adjuvants, but not all adjuvants are surfactants. For example, drift control additives and safeners are not surfactants.

Choosing the Right Adjuvant

Here are some factors to consider when deciding whether to use an adjuvant and how to choose the right one for a particular site and situation.

- Read and follow the label. Is an adjuvant recommended? If so, what type? Do not make substitutions. Note that some product labels may recommend an adjuvant for one type of use or site but prohibit any kind of adjuvant for another labeled use or site. Many end-use formulated products already have adjuvants, and adding adjuvants "on the fly" can decrease efficacy. Suppose, for example, that a certain product is formulated with a wetting agent. If you add another wetting agent when you mix and load a foliar-applied spray, the product may not give better spreading and coverage. Instead, the extra adjuvant may increase runoff, reduce deposition, and even damage the target plant.
- Use only those adjuvants manufactured for agricultural or horticultural uses. Do not use industrial products or household detergents in pesticide spray mixes.
- Remember that no adjuvant is a substitute for good application practices.
- Take adjuvant performance claims "with a grain of salt." Be skeptical of claims such as "improves root uptake" or "keeps spray equipment clean" unless a reliable source can provide research-based evidence to support them. Only use adjuvant products that have been tested and found effective for your intended use.
- Test spray mixes with adjuvants on a small area before proceeding with full-scale use.

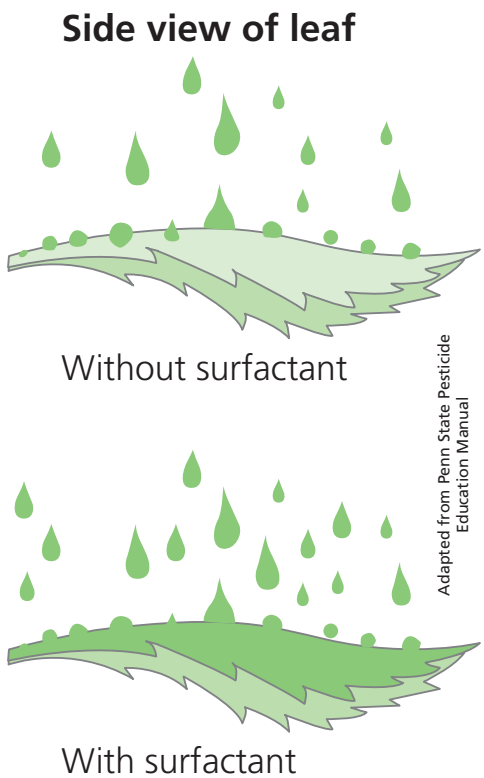


Figure 4.1
Surfactants increase the ability of the pesticide to spread evenly over the surface of a leaf or fruit.

SUMMARY

The ingredients of a formulated pesticide include both active and inert components. The active ingredient controls the pest. Inert ingredients include carriers or diluents and adjuvants. The type of formulation may be provided in the identifying information on the front panel of the label. (The SDS for a product will describe the formulation and also provide information about hazardous inert ingredients.)

Learn what formulations are available for the pesticide active ingredients you will use. To decide which formulation is best for a specific site and situation, you must know the properties—and be able to evaluate the pros and cons—of various formulation types. You must be familiar with formulation types and active ingredient properties in order to understand the characteristics of the products you use and apply them properly.

Most end-use pesticide products contain adjuvants. Although adjuvants themselves lack any direct pesticidal activity, they are added to pesticide formulations to improve product performance. You should know when and how to use an adjuvant.

In summary, you must consider several factors when choosing a pesticide formulation. These include the risks and benefits associated with the options available, the practicality of using a specific formulation in a particular site to control the target pest, and whether the formulated product will provide effective control. Understanding the properties of common formulations before choosing a pesticide will help you avoid problems and apply your product in an effective and efficient manner.

Review Questions

CHAPTER 4: Pesticide Formulations

Write the answers to the following questions, and then check your answers with those in Appendix A.

1. **The name "X-Pest 5G" on a pesticide label indicates a:**
   - **A.** Granular pesticide with 5% active ingredient.
   - **B.** Granular pesticide with 5% inert ingredients.
   - **C.** Gel pesticide with 5% active ingredient.

2. **Which is the pesticide formulation process by which solid particles are dispersed in a liquid?**
   - **A.** Emulsion.
   - **B.** Solution.
   - **C.** Suspension.

3. **Which liquid pesticide formulation consists of a small amount of active ingredient (often 1% or less per unit volume)?**
   - **A.** Microencapsulated (M).
   - **B.** Ready-to-use (low-concentrate) solution (RTU).
   - **C.** Ultra-low volume (ULV).

4. **Which liquid pesticide formulation may approach 100% active ingredient?**
   - **A.** Aerosol (A).
   - **B.** Emulsifiable concentrate (EC).
   - **C.** Ultra-low volume (ULV).

5. **Which is a disadvantage of both EC and ULV formulations?**
   - **A.** Difficult to handle, transport, and store.
   - **B.** Require constant agitation to keep in suspension.
   - **C.** Solvents may cause rubber or plastic hoses, gaskets, pump parts, and other surfaces to deteriorate.

6. **Which dry/solid formulation is mixed in water and reduces the risk of inhalation exposure during mixing and loading?**
   - **A.** Soluble powder (SP).
   - **B.** Water-dispersible granule (WDG) or dry flowable (DF).
   - **C.** Wettable powder (WP).

7. **Which type of dry/solid pesticide formulation consists of particles that are the same weight and shape?**
   - **A.** Bait.
   - **B.** Granule.
   - **C.** Pellet.

8. **Which is an advantage of microencapsulated materials?**
   - **A.** Delayed or slow release of the active ingredient prolongs their effectiveness.
   - **B.** Their pesticidal activity is independent of weather conditions.
   - **C.** They usually require only short restricted-entry intervals.

9. **Which type of adjuvant functions as a wetting agent and spreader (i.e., physically altering the surface tension of spray droplets)?**
   - **A.** Buffer.
   - **B.** Extender.
   - **C.** Surfactant.

10. **Which type of adjuvant increases the viscosity of spray mixtures?**
    - **A.** Sticker.
    - **B.** Extender.
    - **C.** Thickener.