



Herbicide Formulations and Adjuvants

While the selection of herbicide is a key element in controlling unwanted plants, consideration must also be given to the *formulation* and *adjuvants* used in the treatment. This module will provide a brief description of the many formulations and adjuvants common to right-of-way work, how to choose the proper material, and the influence they can have on an application.

Pesticide Formulations

The formulation of an herbicide refers to the material it is carried in or on, and its concentration in that carrier. Every herbicide product is a combination of active ingredients and inert ingredients.

The same herbicide can be available in more than one formulation. The first way in which formulations are classified is LIQUID or DRY. All liquids are applied through sprayers or spot applicators. Dry products can be diluted in water and applied as a spray, or applied directly as granules or pellets.

Descriptions of formulation types will be followed by examples from the Pennsylvania statewide herbicide contract, when available.

Liquids

Herbicides in the liquid form can be water soluble, suspensions, or emulsifiable concentrates. All can be mixed in water, and some can be mixed in oil carriers as well. All can be applied as spray solutions. Some, like 'Velpar L', can be applied undiluted to the soil around unwanted plants using a specialized spot gun. The herbicide is then absorbed by roots in the treated area.

Water Soluble Formulations

Water soluble (S) formulations of herbicides mix thoroughly with water and stay in solution even without agitation. They do not separate and settle out in their containers, even if stored for long periods of time.

PA Contract Examples: Arsenal (2S), Garlon 3A (3S), Aquaneat (4S), Glyphomate 41 (2.8 S).

Suspensions

In products that are labeled as flowable (F or L), or aqueous suspensions (AS), the herbicide is bound to very small particles that are suspended in a water base. They pour very smoothly, and will readily mix with water. They form suspensions in the spray solution and can settle out if not continuously agitated. After mixing, these products should be used or drained from the tank before allowing them to set for an extended time. If allowed to set without agitation enough particles can settle out of the suspension and clog the sprayer. Also, if these products are stored for more than a year they begin to settle out and form 'sludge' at the bottom of the container that may be difficult to re-suspend, even with thorough agitation.

PA Contract Examples: none

Examples of non-crop products: Surflan AS (4AS), Diuron 4L

Emulsifiable Concentrates

Emulsifiable concentrates (E, EC) are products that contain *emulsifiers*, and form stable oil:water mixtures. Emulsifiers are able to wrap around oil-soluble chemicals and suspend them in a water-based (aqueous) solution. Milk is an example of an emulsion. Small droplets of oil (fat) are suspended in an aqueous liquid. When the ingredients of an emulsifiable concentrate herbicide are added to water, the mixture becomes 'milky'. Emulsions require some degree of agitation to prevent separation.

PA Contract Examples: Tahoe 4E, Vista (1.5E)

Ready to Use (RTU)

RTU products are premixed combinations of an herbicide and the carrier in which it is applied. For commercial applications, most RTU products are concentrated mixtures intended for stem or stump treatment.

PA Contract Example: Pathfinder II

Liquid Formulation Issues

Unless clearly stated otherwise on their label, all liquid formulations should be protected from *freezing*. Liquids also have a shorter shelf life than dry products.

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Except for the water soluble products, they can separate into phases in the containers that may be difficult to remix. Flowables or aqueous suspensions may separate into a liquid and solid phase, with the solid phase accumulating on the bottom of the container. If stored too long, it may be impossible to properly mix them again even with vigorous agitation. Buy only as much herbicide as you should need in one year.

Dry Products

Herbicides in dry form can be applied as is, or mixed in water. Granules and pellet formulations are applied dry. Soluble powders, wettable powders, water dispersible granules, dry flowables, and extruded pastes are mixed with water. Many of the newer dry formulations that are mixed with water have extremely low use rates. As a result, package size is greatly reduced making transportation, storage, and handling much easier than in the past.

Most dry products mixed in water form suspensions. In a suspension, the dry product is not dissolved by the liquid. In a solution, the dry product is dissolved, and is no longer visible in its original form. Adding flour to water forms a cloudy mixture. This is a suspension. Adding small amounts sugar or salt to water creates a solution. The resulting liquid is essentially clear.

Granules and Pellets

In all dry products the herbicides are attached to inert particles that are used as the carrier. Granular (G) or pellet (P) formulations consist of relatively large particles with a low concentration of herbicide and are designed to be applied to the soil right out of the bag.

PA Contract Examples: Snapshot 2.5 TG,
Spike 20P

Soluble Powders

This is not a common formulation. Most manufacturers formulate water-soluble active ingredients in liquid form because it's easier - many of these products are the herbicide in water with perhaps added surfactant. Formulating these products as easy-to-use dry products requires more investment.

PA Contract Examples: none

Non-crop Example: Roundup Pro Dry

Wettable Powders

The original dry herbicide formulations were called wettable powders (W or WP). There were some problems associated with mixing them because they were so fine. They were the consistency of flour or talcum powder, and were extremely dusty when handled. The dust was easily inhaled by workers. The powders also tended to hold together, so during weighing and mixing, attempts to pour the powders often ended up with large clumps falling out of the bag and forming clouds of dust. There are currently no products

commonly used by PennDOT that are wettable powders.

PA Contract Examples: none

Non-crop Example: Hyvar X (80 W)

Water Dispersible Granules & Dry Flowables

In recent years the wettable powders (WP) were improved through a technology that enabled producers to clump the particles together to form aggregates of the particles that would readily disperse in water. These formulations are called water dispersible granules (WDG or DG) or dry flowables (DF), depending on the manufacturer. There is essentially no difference between dry flowable and water dispersible granule formulations. The most recently introduced formulation is the extruded paste (XP). Though it is formulated with a different process, it is used in the same manner as the DF and WDG formulations.

PA Contract Examples: Karmex XP

Water-Soluble Packages

A recent advance in herbicide packaging is the water soluble package. This is used with dry herbicides that are meant to be suspended in water, particularly wettable powders. The manufacturer simply places a given amount of herbicide in each soluble package that corresponds to a common application rate and spray area. These packages are sealed within a foil packet that is opened and discarded by the applicator when mixing. The soluble package itself is then placed into the spray tank where it dissolves and releases herbicide into the spray solution. This reduces measuring, mess, and container disposal.

PA Contract Example: none

Dry Formulation Issues

All of the dry formulations of herbicides are stable and maintain their activity for many years if protected from moisture and stored in sealed containers to prevent losses from volatilization.

Granular products are more expensive to apply than sprayable formulations because they contain less active ingredient per pound of product. This means they cost more to ship, store, handle, and apply. They are mostly used in landscape beds because of the difficulty in getting uniform applications with spray equipment.

Formulations and Measuring

A scale (or balance) or a product-specific graduated container is needed to measure dry products. Unless used indoors there are several problems that occur with scales. Most scales are electric and an electric outlet may be needed. Small, battery-powered balances are available. Wind also can cause problems when measuring dry products outdoors. Liquids can be measured easily and accurately indoors or out. A few measuring cups or graduated cylinders of various sizes

are all that is needed, and wind is not a big factor.

To improve ease of measuring, many dry products come with a container graduated in units of weight, rather than liquid volume. These containers are specific to one product, and should not be used for different products. Another approach to making using dry products easier is to package the herbicide in smaller units so that whole bags are used, rather than having to measure a sample from a larger bag. 'Krovar I DF' comes in a box of 6 lb bags. If you're applying 6 lb per acre, it's one bag per acre. If you're applying 8 lb per acre, it's four bags for three acres. As long as you mix quantities that require whole bags, you never need to weigh material from a bag and store a part-empty bag.

Formulations and Mixing

Two or more herbicides are often *mixed* together for a single application. Only those materials that are compatible should be mixed together. Incompatibilities are often indicated on the product label. Proper mixing begins with filling the spray tank with at least half the water you intend to use. The materials are then added in the following order:

1. adjuvants for antifoaming, buffers, compatibility
2. wettable powders, water dispersible granules, or dry flowables (WP, WDG, DF)
3. water soluble (S, SP)
4. flowables, suspensions (L, AS)
5. emulsifiable concentrates (EC)
6. other adjuvants
7. drift control agents

The remaining water is added to the spray tank once materials are added.

Effect of Formulation on Herbicide Activity

The formulation of an herbicide can affect the level of weed control it provides, and the risk of injury to desirable plants.

Granular vs. Sprayable

Granular forms of an herbicide are generally safer to non-target vegetation than sprayable formulations because as long as the foliage is dry, they bounce off and land on the soil. Sprayable formulations applied over-the-top cover the foliage with a uniform layer of herbicide. So granular forms of an herbicide are safer for use in landscape plantings, but may not provide as good control as sprayable forms.

For example, Goal and Ronstar are preemergence herbicides used in nurseries that provide weed control through contact activity. They form a chemical barrier on the soil surface and burn off weed seedlings that grow through it. Applied in the granular form, they are very safe on a wide range of ornamental plants. If applied to

the same range of plants in the sprayable form they can severely injure or kill them.

Water Soluble vs. Emulsifiable Concentrate

Some herbicides are available in both soluble and emulsifiable formulations. An emulsifiable concentrate usually contains an oil-soluble active ingredient, often called an 'ester' formulation. The ester form provides somewhat better weed control when applied to foliage, because the oil-soluble fraction penetrates the waxy coating on leaves better than the water-soluble fraction of the mixture. However, ester formulations are much more volatile. This means they should not be applied in hot weather because of the risk of the applied material volatilizing off the leaf and drifting onto nearby desirable plants.

Emulsifiable concentrate formulations are also better for stem treatments because they can be mixed in an oil carrier, which penetrates bark better.

Examples: Garlon 3A (water soluble, amine formulation) and Garlon 4 (emulsifiable concentrate, ester formulation)

Active Ingredients

'Active ingredient' can be a confusing term when applied to herbicides because it is not used consistently, especially with liquid products.

In a general sense, 'active ingredient' is the herbicide in the formulation. In a more specific sense, 'active ingredient' is the particular formulation of the herbicide in a specific product.

Liquid Formulations

A liquid herbicide may be available in different chemical variations to make it water-soluble or oil soluble. 'Garlon 3A' is water-soluble, and the active ingredient is an *amine salt* formulation of triclopyr. 'Garlon 4' is oil-soluble, and the active ingredient is an *ester* formulation of triclopyr. However, the formulated herbicide is often not the form of the herbicide that is biologically active in the plant. In the case of the triclopyr formulations, the amine or ester chemical chains detach from the triclopyr molecule once it has entered the plant.

Liquid formulations are described by the pounds of the herbicide per gallon, or pounds of *acid equivalent* per gallon. This is because the 'unformulated' molecule of herbicides is an organic acid. Other descriptions of liquid herbicides can be misleading.

A label will often show the percent active ingredient by weight. Sometimes active ingredient is listed in units of pounds per gallon. Neither of these descriptions are useful if you are trying to compare products with the same herbicide but different formulations. Table 1 illustrates how percent by weight and pounds of active ingredient per gallon do not provide enough information to compare different products. Only comparing pounds

Table 1. The glyphosate products below have different active ingredients and concentrations. This illustrates the importance of comparing the acid equivalent, rather than the active ingredient between products. IPA is the abbreviation for isopropylamine salt, the most common formulation of glyphosate herbicides.

product name	active ingredient (ai)	active ingredient % by weight	active ingredient lb/gallon	acid equivalent (ae) lb/gallon	product needed for 0.75 lb ae fluid oz.
Roundup Pro	IPA salt	41	4.0	3.0	32 oz
Glyphomate 41	IPA salt	41	3.8	2.8	34 oz
Touchdown Pro	diammonium salt	34	3.6	3.0	32 oz
AquaNeat	IPA salt	54	5.4	4.0	24 oz

of acid equivalent per gallon gives you an 'apples to apples' description of the products.

As shown in Table 1, the glyphosate products are the most prominent example potentially confusing product descriptions. 'Roundup Pro' is an isopropylamine salt of glyphosate, while 'Touchdown Pro' is a diammonium salt of glyphosate. 'Roundup Pro' contains 41 percent of the active ingredient by weight, while 'Touchdown Pro' contains 34 percent by weight. Yet each product contains 3 lbs acid equivalent per gallon of glyphosate. Despite containing different amounts of active ingredient, they contain the same amount of glyphosate - the isopropylamine chain added to glyphosate in 'Roundup Pro' is a bigger molecule than the diammonium chain added to glyphosate in 'Touchdown Pro'. 'Glyphomate 41' has the same active ingredient as 'Roundup Pro', and the same percent-by-weight of active ingredient – yet it has less acid equivalent per gallon (!). 'Glyphomate 41' is a *lighter* formulation. A gallon of 'Glyphomate 41' weighs about 9.3 lbs, while a gallon of 'Roundup Pro' weighs about 9.8 lbs. These examples point out why it is important to compare liquid products based on acid equivalent.

Dry Formulations

Dry formulations are usually described in a more straightforward manner. They are described as percent herbicide by weight of a dry material. There is no issue of the density of the product as there could be with a liquid. A pound of feathers weighs the same as a pound of lead. Dry products with the same active ingredient can simply be compared by their percent herbicide by weight.

Spray Adjuvants

Adjuvants are non-pesticide materials added to spray mixes to improve the performance of the application. These additives are commonly categorized as *activator* or *utility* adjuvants. Activators can be thought of as products that improve herbicide performance after the spray has contacted the leaf surface. Utility adjuvants improve your ability to get the herbicide to the leaf surface.

Activator Adjuvants

Water is a *polar* molecule - it has one end that has a negative charge, and the other has a positive charge. Because of this, water molecules bind together (positive of one molecule to negative end of another molecule) quite strongly. The 'pull' between water molecules is often stronger than the 'pull' between water molecules and the surface they are contacting. This is why water forms beads on a smooth surface like a recently waxed car, rather than spreading and laying flat. Leaves are covered by waxy, water repellent surfaces. Spray solutions that are applied to these surfaces tend to bounce or run off of them just like the water off of the just-waxed automobile.

Activator Adjuvant Functions

Activator adjuvant products perform several functions - they serve as wetting agents (or spreaders), stickers, humectants, and penetrants.

Wetting Agents or Spreaders

A wetting agent reduces the surface tension of water, so that a droplet beads less, lays flatter on the leaf surface, and covers more leaf surface area. Wetting agents are called *surfactants*, which is a contraction of 'surface active agent'. Surfactants are the primary ingredient in most activator adjuvants, so most of these products are called surfactants.

Stickers

A sticking agent helps the herbicide ingredients, particularly dry ingredients that were suspended in water, stay on the leaf surface after the water has evaporated. The sticking agent remains as a thin film holding the herbicide in place so that it can be absorbed, and prevent wash-off.

Humectants

A humectant retains moisture, or absorbs water vapor from the air to prevent reduce net evaporation. Keeping the deposited herbicide surrounded by moisture as long as possible prevents the herbicide from crystallizing on the leaf surface and increases absorption of the herbicide into the leaf.

Penetrants

The surface of a plant leaf is a waxy cuticle deposited by the epidermal cells. An oil-soluble penetrating agent increases the movement of the herbicide into and eventually through the cuticle so that the herbicide can be absorbed into the outer layer of cells.

Surfactants

As stated above, most products described as 'surfactants' actually contain ingredients that act as stickers, humectants, and penetrants as well. Therefore, an effective surfactant product will increase the wetting of the leaf surface, the retention of the herbicide to the leaf surface, the drying time of the deposited droplets, and movement of the herbicide into and through the leaf cuticle.

Surfactants may be nonionic (no net electrical charge), cationic (net positive charge), or anionic (net negative charge). Cationic and anionic surfactants can be regarded as specialty products, and are used infrequently. Nonionic surfactants are by far the most commonly used.

Surfactants are not regulated as stringently as pesticides, so the distinction of what components of the products are active or inert is left to the manufacturer to describe. There are unscrupulous manufacturers who contribute to the impression that surfactants are 'snake oils' and have no real effect on spray performance. This is not the case, but it can be difficult to determine which products are truly beneficial. For commercial use, purchase only surfactants that contain at least 80 percent active ingredient. Be wary of products that list isopropanol (or isopropyl alcohol) as a functioning agent contributing to the active ingredients. Isopropanol is a filler ingredient.

PA Contract Example: Timberland 90

Crop Oils

Oil-based products that emulsify in water are used as activator adjuvants in place of surfactants. These products are described as 'crop oils' or 'crop oil concentrates'. The oil portion of these products can be petroleum or vegetable-based, but must be *phytobland*, which means the oil is highly refined and will not damage plant foliage by itself.

The distinction between a crop oil and a crop oil concentrate is the amount of the non-oil component, usually described as surfactant or emulsifier.

crop oil - contains up to 5 percent on a weight basis of emulsifier. The remainder is phytobland oil.

crop oil concentrate - contains 5 to 20 percent on a weight basis of surfactant, and at least 80 percent by weight of phytobland oil.

Crop oils are often recommended instead of nonionic surfactants when the herbicide active ingredient

is oil soluble, or to enhance the foliar activity of a high-rate (older chemistry), suspended herbicide. The most common example of this was applying the herbicide *atrazine* with crop oil to enhance control of quackgrass in corn.

PA Contract Example: Peptoil

Utility Adjuvants

Adjuvants that aid in getting the spray to the leaf surface are described as utility adjuvants. Examples of these products include drift control agents, compatibility agents, defoamers, and colorants.

Drift Control

Drift is a concern for anyone applying herbicides. Small droplets can be carried by wind and contaminate adjacent areas or crops. *Drift control agents* are long-chain molecules that increase the attractive forces within the water, and reduce the amount of small droplets that separate from larger drops. Water that contains drift control agents has a 'stringy' or 'snotty' quality to it. In sprayers where the spray solution is recirculated, the effects of the drift control agent are reduced over time as the long chains are sheared with repeated passage through the pump.

Drift control products vary in their concentration. Highly concentrated products are added in small quantities and need to be mixed thoroughly. You can think of the long-chain molecules in a high-concentration product as being 'balled-up', and it takes time for the chains to open up and react with the water. Highly concentrated products have 30 percent active ingredient. Some products have active ingredient concentrations as low as 1 to 2 percent. The drift control agent molecules are already 'unwound' and mix readily in the sprayer.

The trade off between these types of products is cost vs. mixing time and effort. Concentrated products provide more active ingredient per unit cost, but are harder to work with.

PA Contract Example: Arborchem 41-A

Compatibility Agents

These products are added to spray mixtures to alleviate problems associated with two products that won't readily mix. This is most common in agricultural applications where herbicides are applied in liquid fertilizers.

An example in right-of-way applications is using propylene glycol to improve the mixing of the water-soluble herbicide 'Tordon K' into a combination of basal oil (an oil carrier) and the oil-soluble 'Garlon 4' for basal bark applications.

Although compatibility problems are not typically encountered with the products used in right-of-way applications, you should consider conducting a *jar test*

the compatibility of unknown products. The jar test is simply mixing ingredients in a glass jar, in the same order and concentrations intended for the larger spray tank. Once added, the jar should be shaken to simulate agitation. After it has been shaken let the jar sit a few minutes and see if the products begin to layer, or quickly drop out of suspension.

PA Contract Example: none

Defoamers

Defoamers break down foam that may develop within the tank during agitation. This is a common problem with herbicide mixtures containing glyphosate. It is better to add defoamer during mixing to prevent foam, rather than trying to break it down after it has formed.

PA Contract Example: Arborchem Dry Defoamer

Colorants

Colorants are used to increase visibility of the spray. These products are added to the spray mix to allow the applicator to determine the spray pattern and coverage. Both water and oil-soluble colorants are available. The most common use of colorants for roadside applications is in basal bark and stump treatment solutions. Using a colorant reduces skips and double application. It is important to use a colorant specifically formulated for use in oils, rather than using a product that is marketed as being suitable for aqueous or oil mixtures.

PA Contract Example: Bullseye

Summary

Formulation is what makes an herbicide easier to handle, mix, and apply. Understanding the type of formulation your product is will help you use it more effectively. The best source of necessary information about product formulation is its label – read it.

Adjuvants help your herbicide work better, by increasing the amount of applied material that reaches the target, and helping that applied herbicide get into the target – whether it's a leaf or the stem.

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