Back to basics: A review of pesticide formulation types

Each of the various formulation types fills a different purpose and requires special handling.

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A variety of formulation types are available for pesticide products, and multiple types of formulations may be available for a given active ingredient chemistry. Understanding the physical properties of the various formulations is vital to using them correctly and getting the best performance. This article is intended to review the fundamentals of some of the primary formulation types that a pesticide user might encounter and perhaps serve as a reference when questions about formulations arise.

As all formulation types have advantages and disadvantages, this article is intended as an objective review of the various formulation types and associated issues and does not seek to persuade users to select one type over another. Furthermore, although this article discusses various formulation practices, nothing in it should be construed as advocating engaging in any formulation practice or practicing any technique without obtaining the required licenses and observing all advisable precautionary measures for the handling of pesticide products.

Figure 1. Formulations of pesticides used on turfgrass include (left to right): water-dispersible granule (WG), flowable or suspension concentrate (FL/SC), emulsifiable concentrate (EC) and microemulsifiable concentrate (MEC).

Flowable or suspension concentrate (FL or SC)

Description

A flowable formulation contains tiny particles of active ingredient suspended in a liquid (usually water) and milled to reduce the average particle size. For active ingredients that are more dense than water (most are), suspension agents are added to prevent the solids from settling in the packaged product. Among other inert components, wetting agents are usually needed to keep the solid surfaces wetted in water because most active ingredients tend to be hydrophobic.

Physical properties

Flowables typically have a higher viscosity (are "thicker") than water alone, because of the presence of thickeners/suspension aids. Developing a flowable is a balancing act between the need to keep the viscosity high enough that particles do not sink rapidly, but low enough that the material pours out or pumps easily. Upon dilution in a spray tank, the solids disperse in the water.

What to watch out for

Upon dilution in water, the suspension aids also get diluted; thus, the solids can then settle quickly to the bottom of the mix tank. Clearly, it is critical that agitation be maintained on dilution. Depending on the formulation, the solids can be difficult to resuspend once they have settled.

In addition, it is important to prevent air entrainment in the system, which can lead to foaming. When air bubbles get trapped in water as in the case of foam, wetting agents can migrate away from the surface of the active ingredient and toward the air-water interface of the bubbles. This can cause the active ingredient to "de-mix" from the water, forming aggregates that clog strainers or stick to tank surfaces.

When tank-mixing a flowable or suspension concentrate with emulsifiable concentrates, it is important to watch out for a phenomenon called *heterogeneous flocculation,* in which the solid crystals of a flowable or suspension concentrate get incorporated into the emulsified oil droplets, again leading to large aggregates or clumps. Finally, it is good practice to shake or mix flowables in their container well before use, especially if this is recommended on the product packaging/label.

Emulsifiable concentrate (EC)

Description

An emulsifiable concentrate is a solvent-

based (oil) system that contains active ingredients dissolved in a solvent and emulsifiers. It is designed to form an oil-in-water emulsion upon dilution.

Physical properties

Because ECs are solvent-based, the physical properties can vary widely depending on the solvent system used. The solvent type can affect product qualities such as odor, viscosity, flammability and potential for phytotoxicity. Upon dilution in water, the solvent or oil phase forms an emulsion in water that will eventually separate out. The formation of this emulsion is often referred to as *creaming.* The oil droplets coalesce, forming larger droplets, eventually separating out (think oil-and-vinegar salad dressing). The time over which this occurs can vary with different products.

What to watch out for

Order of addition is important when tank-mixing ECs. For proper dispersion of all components, emulsifiable concentrates should be added last when tank-mixing multiple formulations. ECs may be more phytotoxic to plants than other formulations. Sometimes this is purely an effect of the solvent system used; other times the solvent may allow an active ingredient from another tank-mix partner to penetrate plant tissues too easily or quickly. This is especially problematic for active ingredients that are intended to remain on the leaf surface and not penetrate plant tissues.

Suspoemulsion (SE)

Description

A suspoemulsion is a water-based product that contains both suspended solids (like an SC) and emulsion droplets (like an EC after dilution). As with SCs, suspension aids are needed to prevent settling of the solids or creaming of the emulsion droplets. These tend to be among the more difficult formulations to design properly.

Physical properties

Suspoemulsions have viscosities much higher than water. They are designed to disperse readily upon dilution in water. Like SCs, they require good agitation after dilution to maintain a homogenous dispersion.

What to watch out for

One potential problem with SEs is a phenomenon known as *heterogeneous flocculation.* Very strong agitation in a spray tank can cause the solids to penetrate the oil droplets, leading to flocculation that can, in the most severe cases, lead to clumping of the particles and screen blockage. A well-designed SE should be devoid of this problem, but other tank-mix partners could increase the likelihood of occurrence, even for a very robust system. As with SCs, agitation should be maintained upon dilution in a spray tank.

Wettable powder (WP)

Description

WPs are dry formulations containing the active ingredient, often a carrier and other ingredients. They are milled to reduce the particle size to facilitate spraying without clogging nozzles and are designed to disperse in water upon dilution. After dilution, they are similar to flowables in that they exist as solids suspended in water. For this reason, it is important to have adequate agitation because the solids will settle upon dilution. WPs are sometimes packaged in water-soluble bags for ease of handling.

Physical properties

WPs are finely milled powders and can be dusty. They generally do not flow easily, which means it may be necessary to scoop out the material for use if it is not contained in a water-soluble pouch.

What to watch out for

WPs that are not contained in water-soluble packaging can be very dusty. Wearing the proper protective equipment (for example, dust masks) will prevent inhalation of the finely milled particles. WPs packed in water-soluble pouches should always be added to a mix tank first, and the pouch should be allowed to fully dissolve before other tank-mix partners are added. Failure to do so can result in incomplete dissolution of the pouch, which can clog sprayer strainers.

Water-dispersible granule (WG or WDG)

Description

Water-dispersible granules are dry formulations that are similar to WPs except they consist of larger particles and are typically much less dusty. After dispersion in water, they form a suspension of solids. For this reason, adequate agitation must be maintained to prevent settling of the solids.

Physical properties

WGs tend to flow easily, which allows them to be poured, rather than scooped out of a package. The ease of dispersion is highly formulation-specific, and well-designed WGs should disperse fairly quickly.

What to watch out for

Though WGs are usually less dusty than WPs, there can be smaller particles present, sometimes due to attrition (breaking up) of granules during transportation/handling. A well-designed system should be devoid of this problem. WGs usually take more time to fully

GLOSSARY

Air entrainment — The inclusion of air into a liquid by mechanical means.

Flocculation — A phenomenon in which particles aggregate and clump together.

Heterogenous flocculation — Aggregation of two dissimilar particle types, for example, a solid particle aggregating with emulsified oil droplets.

Micelles — Tiny aggregates of surfactants in a liquid that can contain a second liquid or molecule that is insoluble in the surrounding liquid. For example, detergents form micelles in water to trap oils and dirt so they can be washed away.

Micron — One millionth of a meter (about 0.00004 inch). The average human hair is about 100 microns in diameter.

— R.C.

disperse in water than other formulations, so good mixing practices are important.

Soluble liquid (SL)

Description

Soluble liquids are usually water-based products that contain a dissolved active ingredient (maybe a salt). This is one of the formulation types that actually contains dissolved molecules, not suspended particles.

Physical properties

SLs tend to have lower viscosities than SCs (closer to that of water). They mix easily in water and require minimal agitation after dilution, though some actives are dense enough to settle out over time.

What to watch out for

Because SLs can contain the salt form of an active ingredient, the overall salt concentration in the spray tank can be higher than for other formulations. This can sometimes lead to flocculation of other tank-mix partners such as SCs or ECs.

Microemulsifiable concentrate (MEC)/microemulsion concentrate (ME)

Description

A microemulsifiable concentrate is analogous to an EC, in that it is solvent-based and contains dissolved active ingredients, but unlike an EC, an MEC forms a *micro*emulsion — not an emulsion — upon dilution in water. Sometimes products are sold as water-based microemulsion concentrates (ME) and generally have a lower concentration of active ingredient than MECs. MECs typically contain more surfactants than most other formulations.

Physical properties

True microemulsions are thermodynamically stable water-based systems containing a water-insoluble component. This means that within a given set of conditions, the oil phase is stable and will never separate out. In addition, microemulsions are composed of extremely tiny particles (similar to micelles) that can be as small as 0.01 micron. This makes the diluted product transparent because light scattering is reduced. By comparison, most coarse emulsions can have average particle sizes on the order of 1 to 5 microns.

MEC/ME formulations generally mix easily and require minimal if any agitation to keep the solution homogenous. They have also been found to be less prone to tank-mix incompatibilities. Some products behave like an MEC (transparent upon dilution), but they are not true microemulsions in accordance with the scientific definition, that is, they are not thermodynamically stable.

What to watch out for

Because many MECs contain a solvent system, the same precautions that apply to ECs can apply here with one caveat: solvents that are safer for plants can be used for these products. These formulations tend to be devoid of phytotoxicity issues seen in some ECs. MEC/MEs tend to contain more surfactants than other formulation types, so keep an eye out for foaming.

Granules (GR)

Description

Granules are dry products that are designed to be spread over a surface using spreader equipment (for example, centrifugal spreaders, drop spreaders). They are made up of carrier particles that contain the active ingredient.

Physical properties

The size, shape and uniformity of GR particles depend very much on the product. Well-designed GRs should be devoid of significant amounts of dust and should flow very easily through spreader equipment. Some granules are designed to break apart after they have been watered in.

What to watch out for

Be careful when transferring these products to equipment as some contain significant amounts of dust, especially when they are poorly designed. Also watch out for "bridging" of spreader openings by particles, which can reduce flow through the system. Calibration of spreader equipment is important to ensure proper application rates and to avoid getting water or moisture into granular products as this can dramatically affect their application and performance. GRs should be stored in a dry place, and open bags should be kept sealed when not in use.

THE RESEARCH says . . .

- **A variety of** formulation types are available for pesticide products.
- **Formulations may be** liquid or solid, powders or granules, water-based or oil-based.
- **Understanding the physical** properties of the various formulations is vital to using them correctly and getting the best performance.
- **Small-scale compatibility** tests can prevent tank-mixing errors.
- **Product labels provide** information on proper use.

Conclusion

Achieving the best performance from pesticides requires some basic understanding of the physical properties of various formulation types. Applying this knowledge can help minimize the occurrence of problems encountered when using these products. Given the wide variety of formulation types available and potential problems when tank-mixing, small-scale compatibility tests (jar tests) are a way to discover problems before making large batches for spraying. This is particularly important when a new tank-mix combination is used. Information on proper use of the product should be found in the product label. In addition, some companies offer technical support services that can help solve formulation-related issues.

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