

2.0 INSECTICIDE FORMULATIONS

For a few decades, growers have relied upon the chemicals to meet the increasing demands of feed and fiber of the human population (Knowles 2008). For this purpose, researchers have tried to develop more effective formulations that can be more efficiently applied to crops to optimize the crop production (Green, Hartley et al. 1987). However, different types of formulations are available in the market depending upon the consumer preference, application and their biological activity (Mulqueen 2003).

A formulation is generally referred to as **homogenous mixture of an active ingredient/technical grade material (responsible for killing the target pests)** and **inert ingredients** that may enhance its physical and chemical properties (Burgess 1998). Active ingredients cannot be applied directly in the field because they may be **chemically unstable**, difficult to handle and to apply in field and may not be mixed well in water directly (Rathburn Jr 1985). Therefore, chemicals are formulated with the objectives **to apply them safely with higher shelf life and required biological performance** (Seaman 1990; Mulqueen 2003).

A single technical grade material may be available in different formulations to control different stages or different types of insect pests. For example, a liquid formulation of **spinosad (240SC)** is used to control the **armyworm, American bollworm, thrips and diamondback moth** in different field crops while a **solid formulation of spinosad** is used as a bait to control the fruit fly in orchards and vegetables.

2.1 Types of Formulations

Three main types of formulation which are further subdivided:

2.1.1 Liquid formulation

2.1.1.1 Emulsifiable concentrate (EC)

This formulation shares the **big volume of all the available formulations** worldwide (Knowles 2008). EC is the suspension of **oily liquid active ingredient** mixed with **organic/petroleum based inert solvents** along with **emulsifiable concentrate agent** which allows the concentrate to be diluted **in water to form emulsion**. Percentage of emulsifying and other agents' represented as **inactive ingredients**. These are **bipolar in nature** with one end is **hydrophilic** and other is **hydrophobic**. So, careful consideration is required in selection of these agents to avoid **creaming, flocculation and coalescence of oil droplets**. Non-ionic surfactants usually block copolymers so other polymers are used to stabilize the emulsion (Tadros 1994; Knowles 2008). **Emulsion is of milky in appearance** (Sarwar 2015).

Target pests of EC formulation

These formulations are active against a wide range of pests (**bollworms, whitefly, jassid, thrips, aphid, armyworm and mealybug**) and are adaptable to various kinds of field application equipment like **low volume ground sprayers, hydraulic sprayers, mist blowers** etc.

Examples of EC formulation

Endosulfan (35EC), **Fipronil (5EC)**, Deltamethrin (10EC), Cypermethrin (10EC), Bifenthrin (10EC), Chlorpyrifos (40EC), Esfenvalerate (110EC), Profenofos (500EC), Emamectin benzoate (019EC) and Lambda-cyhalothrin (2.5EC)

Advantages of EC formulation

EC formulations have many advantages (Fishel 2010).

- **Require simple equipment for handling, storage and application.**
- It needs **little agitation** because it does not **separate out or settle down** while spraying.

- It is not abrasive to the equipment used and does not clog the nozzle and pipes.
- It leaves little residues on treated surface like leaves.

Limitations of EC formulation

EC formulations have many disadvantages (Fishel 2010).

- It may cause damage to plants (phytotoxic) at high temperature.
- Accidental exposure of the poison may cause the skin irritation to animals (absorbed through skin).
- There may be calibration or mixing error due to high concentration of active ingredient that leads to the over or under dose problems.
- Some active ingredients are flammable so should be kept away from heat.
- Some solvents may be corrosive to the equipment.



Form of EC available at the shop



Form of EC after mixing in water

Figure 2.1. Emulsifiable concentrate Source Fishel, 2010

2.1.1.2 Soluble liquid/ solutions/ water soluble concentrate (SL / S)

It is limited due its hydrolytic stability and solubility in water but simplest of all the marketed formulations (Knowles 2008). These concentrates constitute the liquid active ingredient and many other ingredients that can easily be dissolved in water to form a homogenous mixture or true solution in spray tank. In its concentrated form, it may be used directly or can be further diluted with carrier (Scott 2007; Sarwar 2015).

Target insect pests of SL formulation

Sucking insect pests of cotton like whitefly, thrips, jassid.

Example SL formulation

Imidacloprid (20SL)

Advantages of SL formulation

- Solution requires simple application equipment as they are easy to handle and measure.
- Not require additional ingredients and completely miscible in water.

Limitation of SL formulation

- Limited in number due to insolubility of active ingredients in water (Anonymous 2000).



Form of SL at the shop

Form of SL after mixing in water

Figure 2.2 Soluble LiquidSource Fishel, 2010

2.1.1.3 Ultra low volume (ULV)

These are highly concentrated active ingredients (more than 8 pounds of active ingredient per gallon) that are dissolved in minute quantity of organic solvents (Sarwar 2015). These products are mostly used solely but can be diluted to some extent in specific carrier like crop or vegetable oil. It is formulated to be used in specific situations and can be sprayed in the form of mist by aerial equipment such as air crafts, helicopters or fixed-wing aircraft fitted with spray booms and also with ultra-low volume applicator (ULVA). ULV formulation requires much less field application rate about 2 to 4 L ha⁻¹.

Target insect pests of ULV formulation

Chewing insect pests

Advantages of ULV formulation

It shares all the advantages of emulsifiable concentrates except the followings

- It can be applied on large areas with less frequent refilling and refueling because of low application rates and little dilution.
- Reduced evaporation rate because oil is used as diluent rather than water.

Limitations of ULV formulation (Anonymous 2000)

- Require special equipment for field application.
- Difficult to confine the insecticide to target place due to high drift hazards.

- Some solvents may deteriorate the pumps, surface and other parts of the spray tank.
- May cause skin irritation because it can be easily absorbed by skin.
- May cause error while calibration and application to high concentration of technical grade material (Anonymous 2000).

2.1.1.4 Flowables / suspension concentrate (F / SC)

Flowables is solution of some insecticides that are not able to be dissolved with any carrier either oil or water. So, it is a suspension of solid active ingredient coated on clay or dust particles in small amount of solid diluent and wetting agent such as water. The wet blend can be further diluted by adding water to make the final volume for field application (Synek 1982; Sarwar 2015).

Target insect pests of F / SC formulation

Chewing insect pests especially American bollworm, armyworm.

Examples of F / SC formulation

Thiodicarb (80DF), Spirotetramat (240SC), Spiromesifen (24SC), Flubendiamide (48SC), Chlorfenapyr (360SC), Methoxyfenozide (24SC), Spinetoram (120SC), Indoxacarb (150SC), Spinosad (240SC), Difenthran (500SC).

Advantages F / SC formulation

- Flowables are easy to handle and apply because of liquid nature.
- They require little agitation and leave little residues after application.

Limitations F / SC formulation

- It may be drain out during mixing and application.
- Flowables settle down in the containers so shake them thoroughly before mixing.
- Solid particles are abrasive to nozzle, pumps and pipes (Mulqueen 2003).



Form of SC at the shop



Form of SC after mixing in water

Figure 2.3. Soluble concentrate

2.1.1.5 Aerosols (A)

Aerosol is the mixture of the low percentage of one or more active ingredients dissolved in inert liquefaction gas and solvent. Insecticides are mostly packed in pressurized containers. These can be ready to use or can be used with electric or gasoline powered aerosol generators. Fine droplets of solution released in the form of fog or mist under pressure.

Target insect pests of Aerosol formulation

These formulations are mostly used for domestic pests like mosquitoes and bugs (WHO 2006; Sarwar 2015). These can also be used in green houses and to limited extent in localized outdoor areas.

Example of Aerosol formulation

Baygon

Advantages of Aerosol formulation

- Aerosols are ready to use formulations.
- These can be easily and safely carried out from one to another place.
- Purchasers can buy small quantity of insecticide.
- Relatively more efficient and for longer period of time.
- Uniform coverage of the area to be treated.

Limitations of Aerosol formulation

- It can be applied to limited areas especially for indoor applications.
- Increased risk of inhalation and difficult to confine to target site due to high drift hazards.
- It is flammable so handle with care.
- May require extra cost for specialized equipment for artificial fog generation.



Figure 2.4 Aerosols (Pressurized form of insecticide, ready for spray)

2.1.1.6 Termiticide concentrate (TC)

It is one of the new formulations. This concentrate comprises of two components. One is the termiticide concentrate which contain one or more active termiticide (70% by weight) including phenylpyrazoles, neonicotinoids and many others while the other is the aqueous medium to which this composition is dispersed (0.01-2% by weight) (Nouvel and Boyd 2016).

Example: Biflex



Figure 2.5 Termiticide Concentrate

There are following methods for application

Broadcast spray

It is applied through low pressure broadcast sprayer.

Sub slab injection.

It involves the drilling of holes in the treated areas (walls, slabs) and injecting the effective amount of termiticide concentrate. Drilled holes should be filled properly after exposure.

Trenching / rodding

It involves the digging or rodding of narrow trenches that are flooded with termiticide. The excavated soil should also be treated with this concentrate before plugging the trench.

Target areas

This concentrate can be applied in pre and post construction areas including building, wood structures, crack, crevices, basements and other hard to reach areas. This can be used on crops by using common crop sprayer.

2.1.2 Solid/ Dry formulations

These are marketed as ready to use formulations (granules, pellets, dusts and baits) and concentrates (wetable powder, soluble powder) that needs further dilution for final application.

2.1.2.1 Wettable powders (WP/ W)

Dry formulation is mixture of finely ground concentrated powder (25-75 %) of active ingredient and solid diluent such as clay, wetting agent and disperser. Wetting agent helps to ties the active ingredient and diluent with water on mixing. It forms suspension when mixed with water in the spray tank because active ingredients are immiscible in water but these particles remain suspended or dispersed in the carrier. So these products must be added in the partially water filled spray tanks and should be constantly agitated to let the particles dispersed in the water. Wettable powders can be applied as spray as well as dust (Sarwar 2015).

Target insect pests of WP formulation

It is mostly used for sucking insect pests of different crops like whitefly, aphid, mites and leafminer of cucurbits.

Examples of WP formulation

Cyromazine (75WP), Pymetrazin (50WP), Hexithiazox (10WP), Buprofezin (25WP).

Advantages of WP formulation

- Easily and safely transported, stored and handled.
- Relatively less harmful to treated surfaces than emulsifiable concentrate.

- It can be easily calibrated and mixed.
- Less skin and eye absorption by animals than other liquid formulations.

Limitations of WP formulation

- Respiratory hazards by inhalation of powder while handling.
- Require constant agitation because it quickly settles down.
- Abrasive to application equipment.
- Block the pipes and nozzle of spray tank.
- Hard to mix in alkaline water.
- Leave visible residues.



Form of WP at shop

Form of WP after mixing in water

Figure 2.6 Wettable Powder Source <http://edis.ifas.ufl.edu/pdf/PI/PI23100.pdf>

2.1.2.2. Soluble powder (SP/ WSP)

It is formulation of finely grounded soluble powder that dissolves readily in water and form true solution. The amount of active ingredient ranges from 15-95 %. These are limited in number because few active ingredients are water soluble (Scott 2007).

Target insect pests of SP formulation

Like wettable powders, it is also applicable against sucking insect pests as well as bollworms and armyworm.

Examples of SP formulation

Trichlorophone (80SP), Acephate (75SP), Acetamaprid (20SP), Methomyl (40SP).

Advantages of SP formulation

- Easy to handle during mixing and storage and safe to transport.
- Easily soluble in water which is the cheapest source for farmers.
- Relatively less harmful to plants (less phytotoxic) and other organisms (less absorption through skin) than petroleum based formulations.
- Formulations packages can be easily disposed of.

Limitations of SP formulation

- Limited in market because all active ingredients are not soluble in water.
- Inhalation hazards while mixing the formulation.



Form of SP at the shop

Form of SP after mixing in water

Figure 2.7 Soluble Powder Source Fishel, 2010

2.1.2.3 Dusts (D)

Dust is the formulation of very fine particles mixed with inert carrier such as clay, chalk, silica, talc or volcanic ash. Some dust formulations are highly concentrated and may contain high percentage of technical grade material so these must be mixed with inert carrier while some products are ready to use and contain a small amount (< 10 %) of active ingredient (Scott 2007).

Target insect pests of Dust formulation

These products are mostly used for seed treatments, indoor (ants, termites, cockroaches) and other parasitic insect pests.

Example of Dust formulation

Coopex dust (permethrin)

Advantages of Dust formulation

- Ready to use formulation and need no further mixing.
- It can be efficiently applied in hard to reach areas by using simple equipment.
- It can be efficiently used where moisture of the spray may cause problem.

Limitations of Dust formulation

- Increased risk of inhalation and drift hazards.
- Residues may be easily moved off by wind and may irritate nose, throat, eyes and skin.
- Dampness may reduce the effectiveness by clogging and lumping of solid particles.
- May provide uneven exposure of the target area.



Figure 2.8 Dust

Source <http://edis.ifas.ufl.edu/pdf/PI/PI23100.pdf>

2.1.2.4 Granules (G)

The technical grade material is similar to dust (1-15 %) and coated on coarse sized and heavier sand or plant material to form granule. These products contain a low percentage of active ingredients (1-15 %) and defined by their particular size of granule (granules passed across 4-mesh sieve and retained through 80-mesh sieve). These are applied as dry and upon contact with water, they start to release toxin slowly (Anonymous 2000).

Target insect pests of Granule formulation

These are used against agricultural, soil (nematodes) as well as aquatic pests such as mosquitoes (Fishel 2010). For agricultural pests (borers of rice and sugarcane) they are being applied in the roots that transfer the toxin to upper parts by absorption.

Examples of Granule formulation

Carbofuran (3G), Cartap hydrochloride (4G), Thiomethoxam (25WG).

Advantages of Granule formulation

- Ready to use formulation without further dilution or mixing.
- Low drift hazards due to large particle size.
- Little risk of exposure to the applicator.
- Slow release rate than powder formulations.
- Can be applied by simple equipment.

Limitations of Granule formulation

- Non-target organisms like birds and other animals are at risk after its exposure.
- Unable to stick to foliage or may require water to release the active ingredient so not efficient in drought conditions.
- Cannot be dispersed uniformly.



Figure 2.9 Granules

Source <http://edis.ifas.ufl.edu/pdffiles/PI/PI23100.pdf>

2.1.2.5 Pellets (P/ PS)

Pellet formulations is resembling to the granules except a thick paste of liquid is coated on the solid carrier as like granule but under certain pressure it is extruded to cut into uniform shapes. Pellets are usually similar in shape and size and mostly applied in localized areas. Pellets are usually similar in shape and size and mostly applied in localized areas (Scott 2007).



Figure 2.10 Pellets, Source <http://edis.ifas.ufl.edu/pdffiles/PI/PI23100.pdf>

2.1.2.6 Baits (B)

Bait formulation is the combination of a toxic technical grade material (< 5%) mixed with any attractant or food based carrier like bran, orange pulp, corn cobs and sugar (Sarwar 2015). Pests are forced to being attracted by the bait and killed by consuming the toxic substance present in it.

Target insect pests of Bait

It can be effectively used for indoor and outdoor pests such as ants, roaches, flies (fruit fly) and even for vertebrate pests.

Example of Bait

Spinosad in Bait

Advantages of Bait

- Ready to use
- Not need to treat the entire area because bait attracts the insect pests.
- It is mostly used for mobile pests.

Limitations of Bait

- Other domestic animals, wild life and children can be attracted and killed by bait.
- Food or other crop may prefer by pests to bait.
- Dead insects may cause space or odor problems.
- It can serve as a food when active ingredient becomes ineffective.



Figure 2.11 Baits

2.1.3 Fumigants (F)

Fumigants are the solid or liquid active ingredients and become gaseous on application at room temperature. Liquid active ingredients may be volatile or may be formulated under high pressure. But some are solids in the volatile pellets or tablets and require humidity or small amount of water of being vaporized. These are active in gas tight atmosphere against all insects irrespective of their mouth parts (Anonymous 2000).

Target insect pests of Fumigants

They are non-selective and used against a wide range of pests.

Example of Fumigants

Methyl bromide, Aluminum phosphide, Dichlorvos, Naphthalene

Advantages of Fumigants

- Fumigants have broad spectrum activity to various insect pests.
- It easily and efficiently penetrates in hard to reach areas like grain bins, cracks, crevices and wood structures.
- Usually single treatment is enough to kill the target pest of that area.

Limitations of Fumigants

- Efficient in properly enclosed areas to prevent the escape of gaseous poison.
- Due to broad spectrum activity, it is also hazardous to non-target organisms.
- Fumigants require specialized training for application due inhalation hazards.
- Insecticidal exposure may require extra cost for specific equipment.



Figure 2.12 Fumigant

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