Pest Control

Compiled by

S.K. Pal and S.K. Das Gupta

Skill Development Series no. 15

ICRISAT
Training and Fellowships Program
International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

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Acknowledgments

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Comments and suggestions from Drs H.C. Sharma, T.G. Shanower, and D. McDonald for compiling this document are gratefully acknowledged. Thanks to Mr S.V. Prasad Rao and Mr Y.P. Lingam for processing this publication.

Contents

Pesticides

Terminology and Definitions

The following are frequently used terms related to pesticides and their application.

Pests — Organisms such as insects, rodents, nematodes, fungi, weeds, birds, bacteria, viruses, etc., which damage the crops and reduce yield. Pests are injurious to human health and/or farmers economic efforts.

Pesticides — Chemicals or mixtures of chemicals that are used for killing. repelling, mitigating or reducing pest damage.

Herbicides — Substances used for inhibiting growth of plants, plant parts, or to kill/destroy the plants.

Defoliants — Substances that initiate leaves to fall.

Desiccants — Substances that cause plant tissue to dry up.

Fungicides — Substances that prevent, destroy or inhibit the growth of fungi in crop plants.

Insecticides — Substances that prevent, inhibit, destroy, kill insects (belonging to Class *Insecta,* Phylum *arthropoda).*

Rodenticides — Substances that prevent, inhibit, destroy, kill rodents (Class *Mammalia, Order Rodentia).*

Miticides/Acaricldes — Substances that prevent, inhibit, destroy, kill or mitigate mites *(Acarina arachnid* arthropods).

Nematicides — Chemicals that prevent, repel, inhibit or destroy members of the Class *Nematoda.*

Molluscicides — Prevent, repel, inhibit or destroy members of the Phylum *Mollusca* such as snails.

Formulation — The form in which a pesticide is sold for use.

Active ingredient (a.i) — is a part of a pesticide formulation which is the actual toxicant sometimes referred to as "technical grade" or "basic pesticide"

Inert ingredients — Substances, other than the active ingredient, which constitute a pesticide formulation.

Classification of Pesticides

Pesticides may be classified according to:

a) the target pest species.
b) their chemical constitution
c) their site of action

Classification based on target pest species

The following explains the classification of pesticides based on target organisms. For certain organisms, subclassifications are also made.

Pesticide classification

Target organisms		Pesticide
Microorganisms	Fungi	Fungicides
	Algae	Algaecides
	Bacteria	Bactericides
Arachnids		Acaricides or Miticide
Insects		Insecticides
Molluscs		Molluscicides
Nematodes		Nematicides
Rodents		Rodenticides
Birds		Avicides
Plants		Weedicides or Herbicides

Classification based on chemical nature

The classification of pesticides based on their chemical nature is rather complex. Modern pesticides are, in general, organic chemicals (compounds with carbon). However, some inorganic compounds are also used as pesticides. The organic pesticides can be subdivided into classes based on their molecular structure. These classes are organochlorines, organophosphates, carbamates, organomercurials, thiocarbamates, acetamides, ureas, etc. Combining the two methods of classification based on target species and chemical nature, a useful classification system is obtained. This is given below.

Pesticides

Inorganic	Insecticides		
	Fungicides		
	Herbicides		
	Rodenticides		
Organic	Insecticides	Organochlorines	Pyrethroids
		Organophosphates	Other organics
		Carbamates	
	Herbicides	Nitropenols	Uracils
		Chlorophenoxy compounds	Triazines
		Dipyridyls	Thiocarbamates
		Ureas	Other organics
	Fungicides	Organotins	Organophosphates
		Organomercurials	Other organics
		Dithiocarbamates	

Appendix IV lists pesticides approved in India under the Insecticides Act, 1968, and their class based on target organisms and chemical nature. It should be remembered that a pesticide may appear in more than one class based on its target species, but will be in only one class based on its chemical nature.

Classification based on site of action

By segmenting insecticides/acaricides and fungicides separately, insecticides/ acaricides can be classified on the basis of their routes of entry into the body system of the target pest. They can be grouped as follows.

i) Stomach poisons.
ii) Contact poisons.
iii) Systemic poisons.
iv) Fumigants.

Stomach poisons

Stomach poisons enter the body of the pest through the mouth during feeding into the digestive tract from where these are absorbed into the systems. Stomach poisons are more effective against chewing insects and useful in controlling insects with siphoning or sponging types of mouth parts (housefly for an example). Examples: dieldrin, sulfur, lead arsenate, etc.

Contact poisons

These poisons enter the body directly through the cuticle by contact with the treated surface of the foliage, stem, etc. These poisons act on the nervous system of the pest. These may also be applied directly on to the body of the pest as a spray or dust. Examples: benzene hexachloride. dichloro diphenyl trichloro ethane, endrin, quinalphos, carbamates, etc. Some of the known pesticides derived from plants also have contact action. Examples: pyrethrum, rotenone, sabadilla. nicotine, etc.

Systemic poisons

These poisons are applied on the plants' surface such as the foliage, green parts of the stem, and near the roots from where these are translocated into the plant tissues. Most of the systemic poisons act as stomach poisons, or both as stomach and contact poisons. The parts of the plant where these poisons have been translocated become lethal to the pests feeding on these parts of the plants. Systemic poisons are more effective against sucking pests. They have a selective action with little effect on the predators and parasites directly, unless acting through the food chain. Translocation of these poisons takes place mostly through xylem vessels. Examples: demeton-o-methyl, phosphamidon. monocrotophos. phorate. carbofuran. dimethoate, mevinphos, aldicarb, etc.

Fumigants

Fumigants are volatile poisons and enter the body of the pests through the respiratory system. These are widely used in controlling stored grain pests. All types of pests can be killed by fumigants irrespective of the types of mouthparts provided a gas-tight atmosphere is ensured (i.e., fumigants are nonselective). Even for soil pests such as nematodes, fumigation is effective. Examples: dichlorvos. hydrogen cyanide, methyl bromide, paradichlorobenzene, ethylene dichloride, carbon tetrachloride, naphthalene, nemagon, aluminum phosphide, etc.

Pesticide Formulations

Pesticides, with a few exceptions, are sold and used as formulated products. Formulating a pesticide improves its performance and increases its environmental safety.

Pesticides are first manufactured as technical grade (active ingredient or a.i). In this form, they are unsuitable for direct use because of the following reasons:

- They have unsuitable physical characteristics. They are generally waxy or lumpy solids or viscous liquids. In this form, they are difficult to apply.

- They have high purity levels and hence the required dose is difficult to disperse. The quantity involved is very small to be evenly and effectively dispersed over a specified area.

- The toxicity of the a.i. is much higher compared to the formulations. Thus, application of a.i. is not only hazardous but also needs specialized training and knowledge in handling.

- The a.i. does not have the ideal physiochemical characteristics which the formulations have.

Formulations contain the a.i. in a definite concentration together with other materials such as inert carriers, emulsifiers, wetting agents, solvents, thickeners, encapsulants, etc.

According to the intended mode of application, the common formulations can be grouped as follows:

A. For spraying after mixing with water/oil

i) Emulsifiable concentrates (EC) (Fig. 1)
ii) Wettable powders (WP or WDP) (Fig. 2 and 3)
iii) Ultra low volume concentrates (ULV)

B. For dry application directly from the container

i) Dusts (D)
ii) Granules (G)
iii) Encapsulated granules

C. For application as a gas or vapor

i) Fumigants (Fig. 4)
ii) Smoke generators or tablets that vaporize
iii) Aerosols and pressurized sprays

D. Other formulations

i) Seed protectants (dry or liquid)
ii) Baits for rodents, slugs, flies, cockroaches, etc.

Type of Formulations

Emulsifiable concentrates (EC)

These are concentrated solutions of the technical grade material containing an emulsifier to help the concentrate mix readily with water for spraying. The emulsifier is a detergent that causes the suspension of microscopically small oil droplets in water, to form an emulsion. When an emulsifiable concentrate is added to water and agitated (i.e., stirred vigorously), the emulsifier causes the oil to disperse uniformly throughout the carrier (i.e., water) producing an opaque liquid. Liquid formulations are easy to transport and store, and require little agitation in the tank. However, care must be exercised in handling the toxic concentrates.

Figure 1. An emulsifiable concentrate (insecticide).

Figure 2. A wettabie powder (insecticide).

Figure 3. A fungicide (wettable powder).

Figure 4. A tumigant.

Wettable powders (WP)

When an inert dust is impregnated with the pesticides, and a wetting agent is incorporated, the resultant powder, if mixed with water with continuous agitation, forms a fine suspension. To formulate a wettable powder, the technical grade of the toxicant is added to an inert diluent and a wetting agent (comparable to a dry soap or detergent) is added in the required ratio, and the whole combination is thoroughly mixed. Wettable powders usually contain 50% of the inert talc or clay but may even be mixed in a proportion of 75% a.i. and 25% other inert substances. Constant stirring of the mixture is generally required after addition of water, as otherwise the suspension may settle to the bottom of the liquid. Wettable powders are easy to carry, store, measure, and mix. However, care must be taken to protect against inhalation during handling.

Dusts

These are the simplest of formulations and the easiest to apply. In a formulated dust, the following two types of mixtures are usually found:

a) Undiluted toxic agent, e.g., sulfur dust used for control of mites and powdery mildew.

b) Toxic a.i. plus an inert diluent. This is the most common dust formulation sold as 2%, 5%, or 10% a.i dust.

Dusts are the least effective and, although prices are lower, have the least economic return. Dusts give poor deposit on the target plants. It has been calculated that not more than 10-15% of the applied material is retained on the surface.

Granular pesticides

This is a formulation in which the chemical is in the form of small granules of inert material, either as a coating on the surface of the inert granules, or as an impregnated toxicant in the granules. The a.i. of the granules varies from 3% to 10% in India, but may be up to 25% in some countries. The size of the granules varies from 20 to 80 mesh (i.e., the number of grits (granules) per inch of the sieve through which they have to pass). Granular pesticides can be applied on to the soil, or may be placed in the whorl of leaves depending on the nature of pest control required.

Granular insecticides may be more economic since precise applications are possible with them. When applied in the soil, they are generally less harmful to beneficial insects such as bees. For systemic insecticides, granule application is excellent since they are placed in the root zone.

Ultra low volume sprays (ULV)

Ultra low volume applications are so formulated that in many instances. they do not need any further dilution or only a small quantity of diluent carrier is needed. The total volume required with the ULV formulations is from 2 to 4 L ha^{-1}. These formulations require specialized application techniques. ULV sprayers, helicopters or fixed-wing aircraft fitted with spray booms are used With ULV applications, drift may be a problem.

Pesticides nomenclature

Pesticides usually have three different names.

i) Chemical name or the name of the active ingredient in pure form,
ii) Common name, and
iii) Trade name/brand name or proprietary name.

Chemical names

The chemical names are usually rather complex. These are made out according to the principles of nomenclature accepted by the IUPAC (International Union of Pure and Applied Chemistry) and/or by CA (Chemical Abstracts). E.g. 2,2-dicholorovinyl dimethyl phosphate.

Common names

For the chemical name of any pesticide, a common name is usually officially selected by recognized bodies such as the International Standards Organization (ISO); the British Standards Institute (BSI); the American National Standards Institute (ANSI), etc. Common names help to avoid confusion resulting from the use of several trade names or proprietary names for the same product marketed by different firms. It is conventional to write the common name starting with a small letter, e.g., dichlorvos (DDVP).

Trade names/brand names

The manufacturer or the formulator selects the brand name/trade name or proprietary name There may be various trade names for a single product and it is conventional to write the initial letter of the trade name in capitals, e.g., Furadan, Nogos, Nuvan, Marvex.

Calculation of Insecticide Dosage

Insecticides may need to be selectively applied for controlling insect pests. Accurately computing the amount of insecticide required for a given area, and uniform application rate is essential for effective control of insect pests.

Form or type of common insecticides

Commercial products available in the market are commonly in the form of a wettable powder (WP), granules, or emulsifiable concentrates (EC).

Common expression of recommended dosages

Insecticide recommendations are often expressed as kilograms of active ingredient per hectare (kg a.i. ha^{-1}) or percentage concentration of active ingredient (% a.i) of the insecticide in the final diluted solution. Therefore, the insecticide should be used in the correct dosage by diluting the exact amount of the concentrated form of insecticide with a predetermined volume of water or other diluent or by spreading the exact amount of granules required over a specific area. To achieve this, it is necessary to calculate the exact amount of insecticide material needed for the area being covered.

Common terms used in insecticide calculations

Expression of concentration

Each commercial insecticide possesses an active ingredient (a.i), the principal chemical compound that acts on the insect. Because this active ingredient is highly toxic it is marketed in a diluted form.

i) In solid formulations such as dust, wettable powder or granules, the active ingredient is mixed with inert material. The concentration is expressed as -

Active ingredient (%) in the total weight of commercial product

$$\text{Active ingredient (\%) in dust, WP. or granules} = \frac{\text{Weight of a.i.} \times 100}{\text{Total weight of WP, dust, etc.}}$$

Example. Sevin 50 WP means there are 50 g of 1-naphthyl-N-methyl carbamate (carbaryl) in every 100 g of commercial WP (50% a.i.).

ii) Liquid formulation Here the a.i. is dissolved in a solvent with an emulsifying agent. It is expressed as an emulsifiable concentrate (EC). The concentration can be expressed in two ways.

a) $$\text{Active ingredient (\%) in EC} = \frac{\text{Weight of a.i.} \times 100}{\text{Volume of EC}}$$

b) Grams L^{-1}

Example: Malathion 20% EC means, 100 mL of commercial product has 20 g of pure Malathion.

iii) Diluent. This is a liquid (water or oil) used to dilute the concentrated active ingredient.

iv) Volume of spray. The amount required to cover uniformly an area or a given amount of foliage. The volume is affected by the sprayer. droplet size. and volume such as:

- o High volume spray (HV) requires 400 L or more ha^{-1}.
- o Medium volume spray (HV) requires 150—400 L or more ha^{-1}.
- o Low volume spray (LV) requires 75-150 L ha^{-1}.
- o Ultra low volume spray (ULV) requires 1-10 L or less ha^{-1}.

Droplet size in LV is 80 microns or less (1 micron = .001 mm).

Recommended dosages

Most insecticide recommendations are given in kg of a.i. ha^{-1}. In this, the volume of spray required ha^{-1} is determined by the type of equipment and its calibration. Recommendations are also given in a.i (%) in the total volume of spray. Here the volume of spray is always specified. In summary:

If the recommendation is given in:	Volume of spray is:
a) Kg a.i ha	a) Dependent on sprayers and their calibration.
b) a.i. (%)	b) Volume specified

Calculations

When recommendation is in kg a.i. ha^{-1}.

i) For WP, dust, granules, etc.

Specification required:

1) Area to be sprayed
2) Concentration of a.i in formulation
3) Recommended rate as kg a.i. ha^{-1}.

Formula.

$$\text{Kg of WP/dust/granules} = \frac{\text{Recommended rate x spray area (sq.m)}}{\text{a.i (\%) in WP x 100}}$$

Example: If Basudin 10G granule (10% a.i.) is used at the rate of 2 kg a.i ha^{-1}, then amount of Basudin 10G required for 2500 m^2 is:

$$\text{Kg of Basudin 10G required} = \frac{2 \times 2500}{10 \times 100} = 5 \text{ kg}$$

ii) For emulsiflable concentrates

Specification required:

i) Area to be treated
ii) Recommended rate as kg a.i. ha^{-1}
iii) Concentration ot commercial EC as a.i (%) or kg L^{-1}

When concentration of EC is in a.i. (%)

Formula:

$$\text{Kg of EC required} = \frac{\text{Recommended rate x area (m}^2\text{)}}{\text{a.i (\%) in commercial EC x 100}} \quad \text{Or}$$

$$= \frac{\text{Recommended rate x area (ha) x 100}}{\text{a.i. (\%) in commercial EC}}$$

Example: Malathion to be sprayed at the rate of 2 kg a.i. ha^{-1} for 8000 m^2 and Malathion EC has 20% a.i. How much liters of Malathion is required?

$$\text{Liters of 20\% Malathion required} = \frac{2 \times 8000}{20 \times 100} = 8 \text{ L}$$

When concentration expressed is in kg a.i. L^{-1}

Formula:

$$= \frac{\text{Recommended rate in kq a.i. ha}^{-1}\text{ x area (ha)}}{\text{Concentration of a.i. in product (kg L}^{-1}\text{)}}$$

Example: Folidol (methyl-parathion) (0.72 kg a.i. L^{-1}) is to be applied at the rate of 1.5 kg a.i. ha^{-1} How much will be required for 3.5 ha?

$$\text{Liters of folidol required} = \frac{1.5 \times 3.5}{0.72} = 7.29 \text{ L}$$

When recommendation is based on a.i (%) in the spray fluid

i) Wettable powders (when diluted with water)

Specifications required:

1 Spray volume as L ha^{-1}
2 Concentration desired as a.i. (%) in spray
3 Concentration of commercial product as a.i. (%)

Formula :

$$\text{WP} = \frac{\text{a.i. (\%) desired x spray volume}}{\text{a.i. (\%) in commercial WP}}$$

Example: To control leaf hoppers in a plot. 2000 L of 0.09% carbaryl is to be prepared. The commercial product to be used is Sevin 50%. How much Sevin is required?

$$\text{Kg of Sevin required} = \frac{0.09 \times 2000}{50} = 3.6 \text{ kg}$$

ii) Emulsifiable concentrates (EC)

Specification required:

1) Spray volume as L ha^{-1}
2) Concentration as percentage ot a.i desired.

3) Concentration of commercial EC as a.i. (%).

Formula:

$$\text{Liter of EC} = \frac{\text{a.i. (\%) desired} \times \text{spray volume}}{\text{a.i. (\%) in commercial EC}}$$

Example: 1900 L of 0.04% endrin spray is to be prepared. How much commercial 19.5% EC is required?

$$\text{Liters of endrin} = \frac{0.04 \times 1900}{19.5} = 3.897 \text{ L}$$

(Please note that endrin is banned in India. This is only an example).

With the above example now determine how much Folidol will be required for each tank load of spray (e.g., a knapsack sprayer).

You are required to know:

1. The capacity of the sprayer tank.
2. The total volume of water (in L) required to spray one hectare with this equipment (find this by sprayer calibration).

Example: Suppose with a knapsack sprayer, the application rate was found to be 200 L ha^{-1} (by calibration). How much Folidol (.72 kg a.i. L^{-1}) will be required for each tank load (20 L capacity) when the recommended rate is 1.5 kg a.i. ha^{-1}?

1. Folidol required for 1 ha = $\frac{1.5 \times 1}{0.72}$ = 2.08 L

2. 2.08 L of Folidol to be mixed with 200 L of water to spray one ha.

3. Since the tank capacity is 20 L, the number of tank loads required to spray will be

$$= \frac{200}{20} = 10$$

4. Therefore, amount of Folidol required $tank^{-1}$ load will be

$$= \frac{2.08 \text{ L}}{10} = 0.208 \text{ L of Folidol per 20 L tank.}$$

Summary

It is essential to calculate accurately the amount of insecticide required $unit^{-1}$ area.

Commercial products are available in the form of wettable powders, granules, dusts, or emulsifiable concentrates.

Recommendations are expressed as kg a.i per hectare (kg a.i. ha^{-1}) or percentage concentration (a.i. %) in the spray volume.

Active ingredient (a.i.) is the actual chemical, which is diluted and sold in the market. This is expressed as a.i. (%) in the formulation.

- Liquid formulations are also expressed as active ingredient (%) of the emulsitiable concentrates [a.i. (%) in EC] or as g L^{-1}.
- Water or oil may be used to reduce the concentration of the active ingredient.
- When the recommendation is given in kg of a.i ha^{-1}, the volume of spray is to be determined by sprayer calibration.
- Recommendations are also given as % a.i. in spray volume. Here the total volume of spray is specified for a given area.
- Note that all the calculations based in this module consider the diluent to be water.
- Calculate the quantity required of commercial product based on:

    1. Spray volume
    2. Amount of a.i. desired or recommended (rate kg a.i. ha^{-1})
    3. Concentration in the commercial product
    4. Area to be sprayed

- Amount of spray to be used for adequate coverage are sometimes specified by the manufacturers or find the volume by 'sprayer calibration'.
- Correct application depends on other factors apart from insecticide calculation. Accurate sprayer calibration, measurement of diluent, uniform application of spray are all steps in achieving a good insect control (refer to sprayer calibration and operation of a knapsack sprayer)
- All precautions recommended by the manufacturer in preparing spray solutions should be observed to avoid injury, contamination, or poisoning.

Use and Operation of a Knapsack Sprayer

To achieve good results of pest control and economic use of pesticides a sprayer has to be in good working condition and sprayer must be calibrated before it is used to avoid over or under application of chemicals.

a) A nozzle output of the sprayer should be checked where the nozzle orifice wears out over a time.

b) The swath width of application is directly effected by the size and the angle of the nozzle. Each nozzle has its characteristic spray angle, as the distance between the nozzle tip and the plant canopy varies, the area covered by the spray material also varies. Therefore, the distance the nozzle is held from the ground or plant must be constant for uniform coverage.

c) Pressure in the tank has to be regulated constantly (with installation of a pressure gauge).

d) Walking speed of the operator should be constant as it is essential to achieve a uniform rate of application.

Steps for calibrating a sprayer

1) Fill the sprayer with clean water, clean its nozzle and strainer, and flush the hose if required.

2) Determine the walking speed of spray operator for a measured distance for at least 3 to 4 times and calculate the average speed.

3) Measure the width of sprayed area.

4) Calculate the area sprayed in one minute by multiplying the width of the swath and distance covered in one minute

Determining the amount of nozzle discharge

1) Refill the tank, discharge the spray with required pressure for one minute into a bucket.

2) Measure the quantity of the liquid collected L min^{-1}. Repeat the above procedure 3 times and use the average figure for subsequent calculations.

Calculation of application rate

Example: If a nozzle discharges 0.4 L min^{-1} and the operator covers 20 m^2 in a minute, then the application rate ha^{-1} is:

$$\text{Application rate} = \frac{0.4 \text{ L min}^{-1} \times 10{,}000 \text{ m}^2 \text{ ha}^{-1}}{20 \text{ m}^2 \text{ min}^{-1}} = 200 \text{ L ha}^{-1}$$

Calculation of sprayer loads

Example:

No. of loads ha^{-1} = Rate of application ha^{-1} + Tank capacity of sprayer

If the tank capacity is 20 L and the rate of application is 200 L ha^{-1}, then the

$$\text{No. of loads } ha^{-1} = \frac{200 \text{ L } ha^{-1}}{20 \text{ L}} = 10 \text{ loads}$$

Maintenance of sprayers

Routine maintenance of sprayer is an essential practice to increase the life of a sprayer. One should avail of all information from the sprayer supplier about assembling, operation, and maintenance of the sprayer:

1) It is advisable to use separate sprayers for different pesticides if possible.

2) Do not use a sprayer for pesticide application if it has been used for herbicides. It is potentially dangerous to use the same sprayer because a little amount of herbicide left may damage a sensitive crop. A sprayer for herbicides should be used exclusively for such chemicals only.

3) Even when a sprayer is used only for herbicides, it should be cleaned thoroughly between changes from one herbicide to another. The same is also true for insecticides.

4) Each part of the sprayer and nozzle should be cleaned thoroughly after each usage.

5) With most chemicals, a thorough washing with water may be sufficient. Washing should be done until the washings are colorless.

6) Addition of a detergent will quicken the process but care should be taken that no trace of detergent is left in the sprayer.

7) For phenoxy compounds, such as 2-4-D or 4-chloro-2-methylphenoxy acetic acid, the sprayer should be washed several times with water and detergent, and sometimes with kerosene to rinse out any chemical soluble in oil. Fill the sprayer with a mixture of water and trisodium phosphate or household ammonia (if neither is available, use a strong detergent solution). Circulate the solution throughout the sprayer and let it stand overnight. Do not use ammonia, if any part of the sprayer is made up of brass. Completely drain next day and thoroughly rinse with water.

8) After use, all spray equipment should be thoroughly dried. All valves should be opened for draining and position the equipment in such a way that all the water either drains out or evaporates. Ensure all moving parts are lubricated after each use so that the equipment will be ready for next use.

Figure 5. Calibration of a knapsack sprayer.

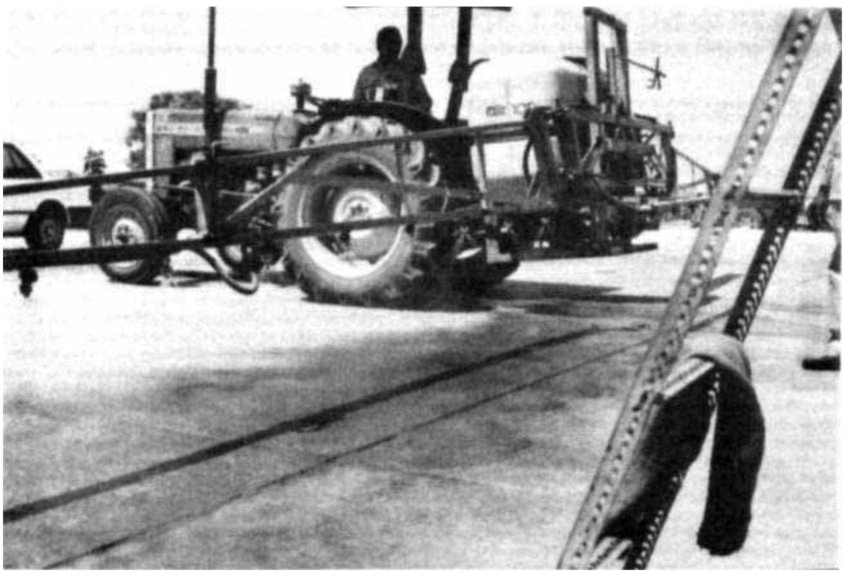

Figure 6. Calibration of a tractor-mounted sprayer.

Pest Surveillance

One of the basic requirements in managing pests on a research farm is constant vigil and surveillance, monitoring of biotic and abiotic components of the crop ecosystem to assess or predict pest outbreaks. Implicit in this concept is the principle of economic threshold level, the point at which pest control is initiated.

The use of precise monitoring techniques coupled with accurate economic threshold levels allows the most effective and efficient use of pesticides. The approach is essential to minimize costs, to maintain stability of the agroecosystem, and to reduce the amount of pesticides released into the environment. However, pest surveillance should not be concerned with pest incidence only. It should be used as a tool to determine the factors which actually cause pest occurrence.

Uses of pest surveillance

1. Surveillance is important for predicting pest outbreaks.

2. The degree of success of the plant protection measures will largely depend upon an effective pest surveillance and monitoring programs.

3. By sampling immature stages of insect/pests, it is possible to forecast the numbers of pests expected in the later stages and spray dates are determined so that the first larvae are destroyed.

Surveillance methods

a) Systematic sampling

Taking samples in the alternate rows and beds, depending upon the size of the plot and the number of rows, it can easily be decided about the rows and beds in which the sampling can be done.

b) Diagonal fashion

The person should start taking samples from one corner and walk diagonally taking samples from alternate beds. Once the samples are taken in one diagonal line, samples should be taken from the nearest other corner. The percentage of pest incidence and the number of pests per plant are to be calculated.

Figure 7. Surveillance crew in a groundnut field.

Figure 8. A pheromone trap in groundnut.

Figure 9. Observation for thrips on groundnut.

Figure 10. Surveillance data sheet.

Controlling pests In a research farm

The plant protection and surveillance unit on a research farm can relieve the researchers from the routine pest control operations so that they can get enough time to conduct research in their respective fields. This unit should maintain a close liaison with the entomologists to solve the pest problems on the farm. The surveillance unit personnel should visit each and every trial on the research farm once in a week (from emergence) and report their findings so as to plan timely pest control operations.

Protection Levels

Depending on the need for pest control, the trials on the experimental station need to be classified into the following categories.

- **Intensive protection**

  Very important crops, e.g., germplasm lines, can be grouped into this category as even a minor damage to such crops is of much concern to the scientists.

- **Research protection**

  Refers to trials protected to avoid some amount of pest damage without interfering with the required results.

- **Economic protection**

  Followed for trials protected to avoid moderate or bulk damage. These trials are sprayed only when severe infestation cause economic damage affecting the progress of further research.

- **No protection**

  Related to trials which are not sprayed at all.

Timing of spray application

Pesticides are frequently applied as a prophylactic or on a fixed calendar schedule irrespective of the occurrence or level of the pest population However, fewer applications are needed if they are timed more accurately and this will reduce selection pressure for resistance. A routine pest assessment is required, preferably aided by a pest forecast of the probable level of infestation, to avoid fixed schedules.

i) **Economic injury level.** It is the lowest population density that will cause economic damage.

ii) **Economic threshold.** The population density at which control measures should be applied to prevent the increasing pest population from reaching the economic injury level.

Apart from counting the number of insects in a crop, various trapping techniques can be used to sample populations, e.g., pheromone traps, light traps, and attractant (such as fishmeal) traps.

Time of sampling and the stage of the life cycle sampled are most important. Detection of eggs is most important to avoid delay in taking the appropriate control measure.

Some larvae are very difficult to find untilthey reach the third or fourth instar while others feed inside plant parts. A pesticide application should be done early, at the start of an infestation of first instar larvae, otherwise less control is achieved.

Important Pests on ICRISAT Mandate Crops

Sorghum

Scientific name of pest	Common name	Identification marks/life stages	Nature of damage
Atherigona soccata (Rondani)	Shoot fly	Eggs: White, cigar-shaped 2 mm length, singly on the under surfaces of the leaf. Hatching period 2-3 days. Maggot: Whitish yellow. 8-10 days. Pupa: 5-10 days.	Causes deadheart and death of seedlings. From 1 week to 1 month. Late sowings more prone to attack.
Chilo partellus (Swinhoe)	Spotted stem borer	Egg: Flattish oval, and tend to overlap like fishscales 10-18 in masses. Hatch in 4-5 days. Larvae: Cream colored with lines of black dots on the body, live up to 19-27 days, bore into stems. Pupates inside stem and adults emerge in 7-10 days.	Leaf feeding, deadheart - causing windowing on the leaves. Upper surface eaten and lower surface intact, stem tunneling.
Mythimna separata (Walker)	Armyworm	Eggs laid in batches of 20-100 within the leaf sheets, leaf folds, or on the soil. Incubation period 4-5 days. Larvae: Dirty pale brown to dark brown with three dark brown dorsal lines. There is a lateral yellow stripe on each side, 29 to 39 days, pupates in soil, adult emerges 7-10 days. Out- breaks occur after heavy rains, floods, and drought following heavy rains.	Defoliator.
Calacoris angustatus (Lethiery)	Earhead bug	Adult: 5 mm long 1 mm width yellowish green. Lays 150 to 200 eggs hatch in a week. Nymphs, first instar orange - red and later turn light green. Nymphs develop to adult. Life cycle less than 3 weeks. Open type heads are less affected.	Sucks sap from the developing grain. Grain attacked will shrivel, reducing crop yield and quality.
Contarinia sorghicola (Coquilett)	Sorghum midge	Adult 1.3 to 1.6 mm long, dark head, brown antennae and legs, and orange - red thorax and abdomen, and grayish hyaline wings. Lays 75 eggs in flowering spikeletes, <1 day life. Larvae 9-11 days, 14-16 days total life, 9-12 generation during one season and results in the build-up of high infestations when sorghum flowering times are extended by a wide range of sowing dates or maturities.	Larvae feed on the ovary, prevents normal grain development.

Scientific name of pest	Common name	Identification marks/life stages	Nature of damage
Helicoverpa armigera (Hubner)	Earhead caterpillar	Eggs: Spherical, yellowish eggs are laid singly on the young sorghum heads. Incubation period 3-4 days. Young larvae whitish green. Fully grown larvae vary from almost black, brown, or green to pale yellow or pink with light and dark stripes. Lasts 18-25 days. Pupates in soil. Adults emerge 1-2 weeks. The moth is large and brown or gray with specks that form a V-shaped mark on the forewings. The hind wings are dull colored, with a black border.	Feeds on the developing grain.
Peregrinus maidis (Ashmead)	Shoot bug	Adults: Yellowish brown females and males dark brown. Females 1 1/2 times larger than males. The nymphs and adults live in groups on the leaves, within leaf whorls, and on the inner side of leaf sheaths. 26 days life.	Nymphs, adults suck sap causing the plants to appear unhealthy yellow. Growth stunted. High infestation at the boot stage may twist the top leaves and prevent the emergence of panicles. Honey dew execration favors the growth of sooty mould.
Rhopalsiphum maidis (Fitch)	Aphids	Aphids dark bluish-green and some what ovate. Winged wingless forms, females give birth to living young without mating, generation remains one week. Winter - active. Yield losses are rare. Rain suppresses population.	The young and adults suck the plant juice. Causes yellow molting of the leaves. Produces honeydew on which molds grow. Also transmits maize dwarf mosaic virus.
Oligonychus pratensis (Banks)	Mites	Eggs (50/female) are laid on under surface of leaves in webbing hatch 3-4 days. Life cycle remains 11 days at 27°C. Hot and dry weather usually increases mite population.	Suck sap from under side of leaves. The infested areas pale yellow to reddish. Fine webbing on lower side.

Apart from the pest species described above there are many pests whose economic importance is low. They are soil pests: wire worms, white grubs, cut worms, etc. Shoot pests — grasshoppers, hairy caterpillars, beetles, leaf weevil, pink borer, etc.

Millet

Scientific name of pest	Common name	Identification marks/life stages	Nature of damage
Several species	Wireworms	Eggs in clusters in the soil. They are minute, oval, and pearly white.	Larvae feed on millet seed they hollow out the grain kernels.
Elateridae: Coleoptera (Click beetles) Tenebrionidae: Coleoptera (False wireworm, darkling beetles)		Larvae: Creamy white but change to a shinning yellow as they grow older. Generation requiring 1, 2 or many years.	Prevents emergence/ germination. Feeds on roots of sorghum and pearl millet.
	Aphids	As described in sorghum.	As described in sorghum.
	Cutworm	-do-	-do-
	Armyworm	-do-	-do-
	Helicoverpa	-do-	-do-

Groundnut

Scientific name of pest	Common name	Identification marks/life stages	Nature of damage
Lachnosterna (Holotrichia) consanguinea (Blanch)	White grub	Adults: Emerge on the onset of first monsoon showers and feed on wild hosts (Babul, *Acacia,* neem, etc.). Grubs: Description as in millet.	The young grubs initially feed on rootlets and later as they grow they eat away the entire primary root resulting in plant mortality.
Aphis craccivora (Koch)	Aphids	Description as in sorghum 5-30 day life span can produce 15-124 nymphs.	Vectors of viral diseases both nymphs and adults suck sap from the tender growing tips, flowers and pegs. Transmits rosette disease.
Empoasca karri (Pruthi)	Jassids	Forty nymphs can be expected from one female. Peak infestation during Aug-Sep. High and well distributed rainfall encourages good population.	Nymphs and adults suck sap from the young leaves. Severe infestation leads to leaf tips yellowing with 'V' marking.
Scirtothrips dorsalis, Frankliniella schultzei (Trybom), *Thrips palmi* (Kami) (Lelhiery)	Thrips	Winter crop suffers more. One life cycle needs about 15 days. Adults live up to 20 days and lay about 40-50 eggs.	Suck sap from tender leaves. Yellowish white patches on the upper surface of the leaves and necrotic patches on the lower surface. Transmit tomato spotted wilt virus.
Aproaerema modicellas (Deventer)	Leaf miner	Soybean highly preferred. One female can lay about 200 eggs (2-3 days), young larva initially mine the leaves, but after 5-6 days comes out and webs the adjacent leaflets together and feed on from inside the webbed leaves. Pupation inside webs. Adults emerge 5-7 days, 3-4 generations in one cropping cycle. Moths attracted to light traps.	Blisters enlarge, becomes brown and dry up. Severe damage looks whole field 'burnt-up.'
Spodoptera litura (F.)	Tobacco caterpillar	Eggs are laid in masses, 150-400 covered with brown scales. Individual can lay up to 2500 eggs, hatches 3-4 days. Larva feeds during nights and hide during day in soil debris.	Voracious foliage feeders. Later instar larvae can cause damage to growing pods.
Helicoverpa armigera (Hubner)	Gram pod borer	Description as in pigeonpea.	Larvae feeds on leaves and flowers.

Chickpea

Scientific name of pest	Common name	Nature of damage
Lactrostera (Holotrichia) consanguinea (Bl.)	White grub	The young grub feed on small roots and organic matter. The affected plants wither and die. The damage in a field occurs in patches.
Spodoptera litura (F.)	Tobacco caterpillar	These insects feed on the foliage and growing tips. Severe infestation causes total defoliation, leaving only bore stems. Beside foliage damage, the late-instar larvae can damage the developing pods particularly in light soils.
Agrotis ipsilon (Hub.)	Cut worm	Polyphagous, nocturnal, stout larva feed on leaves of young plants and cut the older ones at the ground level.
Aphis craccivora (Koch)	Aphids	Aphids infest crops at all stages of growth when conditions are favorable.
Helicoverpa armigera (Hub.)	Boll worm; Gram pod borer	As the pigeonpea.
Plusia orichalcea	Pea semilooper caterpillar	Polyphagous moth with a golden patch on the forewing green caterpillar feed on leaves during Dec-Mar.

Pigeonpea

Scientific name of pest	Common name	Nature of damage
Odontotermes spp *Microtermes* spp	Termite	Wilting of young plants, sometimes produce a hole in the stem just below the soil surface. *Microtermes* spp tunnels into stem and root. Stems attacked by *Odontotermes* spp are covered with below while termites feed upon the stem surface.
Empoasca spp	Jassids	The attacked leaflets become cup shaped and yellow at edges. Severely infected leaflets turn brown-red followed by defoliation and stunting.
Grapholita (Cydia) *critica* (Meyr.)	Leaf webber	Infestation starts at seedling stage and may persist to the reproductive stage. Leaflets are webbed and larvae feed within the web. Growth of shoot is prevented.
Megalurothrips usitatus (Begnall)	Thrips	Severe infestation causes shedding of buds and flowers.
Mylabris pustulata (Thunherb)	Blister beetle	Adult beetles severely feed on flowers.
Helicoverpa armigera (Hubner)	Pod borer caterpillar	They destroy buds, flowers, pods when flowers and pods are not available they feed upon leaflets leaving the veins. Larvae enter into the pod by making a hole and then eat developing and partially mature seed.
Maruca testulalis (Geyer)	Cowpea pod borer	The larvae web leaves, buds pods together and feeds inside.
Exelastis atomosa (Walsingham)	Plume moth	The larvae chew into the bud, flowers, pods. Small holes can be seen in the buds and tender pods.
Etiella zinckenglla (Treitschke)	Lima been pod borer	The larvae are present in the mature and dried pods. The infestation in maximum at the end of the pigeonpea season when temperatures are high. Faecal granules are found inside the damaged pods.
Melanagromyza obtusa (Malloch)	Pod fly	No external symptom until the fully grown larvae chew and make holes in the pods wall. They leave a window for emergence of flies after pupation in pod-damaged seeds are of no value.
Tanaostigmoides cajaninae (LaSalle)	Pod wasp	Attached locules of young pods remain undeveloped. They feed inside the pod and make an exit hole for the emerging wasp, which is smaller than that of pod fly.

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Evaluations

Select the most appropriate answer and check the correct answer at the end of the booklet.

1. Commercial Sevin WP contains 50% a.i. How much Sevin® is required to make 200 L of 0.09% spray solution?

   a) 201 g. b) 205 g.
   c) 211 g. d) 360 g.

2. Dimecron® 50 EC is recommended to control stem borers at the rate of 1.75 kg a.i. ha^{-1}. How much Dimecron will be required to treat 1250 m^2?

   a) 430 mL. b) 431 mL.
   c) 350 mL. d) 437 mL.

3. How much Furadan® (8% a.i.) is required to spray 8000 m^2 at 2 kg a.i. ha^{-1}?

   a) 30 kg. b) 40 kg.
   c) 20 kg. d) 50 kg.

4. Calculate the amount of Folidol® 0.72 kg a.i. L^{-1} required to prepare a spray solution for treating 2.4 ha at the rate of 1.25 kg a.i. ha'.

   a) 4.16 L. b) 4.2 L.
   c) 5.16 L d) 5 L.

5. Rogor® 30% is to be sprayed at the rate of 1 L a.i. ha^{-1} to control thrips. How much Rogor is required to spray 2500 m^2?

   a) 0.85 L. b) 0.83 L.
   c) 0.97 L. d) 1.0 L

6 Monocrotophos® (Nuvacron®) is recommended to control leaf miner on groundnut at 0.75 kg a.i. ha^{-1}. The commercial product has 36% EC. How much chemical is required to spray 2 ha?

   a) 4.8 L. b) 5.0 L.
   c) 3.2 L. d) 4.5 L.

7. To control *Helicoverpa* in pigeonpea 400 L of 0.3% solution is to be prepared with Quinalphos® (25% a.i. in EC). How much chemical is required to prepare the spray solution?

   a) 4.8 L. b) 5.0 L.
   c) 3.2 L. d) 4.5 L.

8. To control head bugs in sorghum, 300 L of 0.33% carbaryl 50 WP is to be prepared. How much chemical is required for the spray solution?

   a) 1.98 kg. b) 2.0 kg.
   c) 1.5 kg. d) 2.1 kg.

9. To control shoot fly on sorghum 0.35% spray solution is to be prepared with Endosulfan 35 EC. How much chemical will be required for 250 L spray solution?

   a) 2.7 L. b) 2.5 L.
   c) 3.1 L. d) 5.1 L.

10. Following data are obtained for calibrating a knapsack sprayer. Find the total volume of spray required ha^{-1}.

Nozzle discharge	min^{-1}	500 mL
Walking speed of the operator		25 m min^{-1}
Width of spray swath		80 cm

a) 270 L. b) 250 L.
c) 280 L. d) 290 L.

11. A tractor mounted sprayer has 28 nozzles fitted 50 cm apart. Nozzle discharge min^{-1} (for one nozzle) is 1.5 L. Tractor speed is 6 km h^{-1}. Find the total spray volume ha^{-1}.

a) 300 L. b) 200 L.
c) 250 L. d) 350 L.

12. The nozzle discharge from a knapsack sprayer is 0.4 L min^{-1} and the operator covered 20 m^{2} min^{-1}. Folidol (0.72 kg a.i. L^{-1}) is to be applied at the rate of 1.5 kg a.i. ha^{-1} with this sprayer. Calculate the (i) application rate of this sprayer, (it) how much Folidol will be required ha^{-1}, and (iii) how much Folidol will be required for each tank load of the sprayer. The capacity of the sprayer is 20 L.

a) 200 L; 2 08 L; 208 mL. b) 250 L; 2.05 L; 205 mL.
c) 235 L; 2.35 L; 245 mL. d) 225 L; 2.25 L; 225 mL.

13. The leafminer is a pest of

a) millet. b) castor.
c) groundnut. d) pigeonpea.

14. The pest that transmits the bud necrosis virus in groundnut crop is

a) shootbug. b) leafminer.
c) spodoptera. d) thrips.

15. The pest that causes dead hearts in sorghum at the seedling stage is/are

a) aphids. b) shoottly.
c) mites. d) midge.

16. Forecasting of a pest incidence depends on the catch of insects in the traps (pheromone and light traps).

a) True. b) False.

17. Decisionmaking on a spray operation depends on the degree of infestation and threshold levels of pest and disease incidence.

a) True. b) False.

18. When the walking speed of the person operating the sprayer increases, the spray liquid ha^{1} decreases.

a) True. b) False.

19. Acaricides are useful to kill ticks, mites, and spiders.

a) True. b) False.

20. Fumigants are chemicals that enter the body of the insect by body contact.

a) True. b) False.

21. Dimethoate belongs to the

a) chlorinated hydrocarbon group.
b) carbamate insecticide group.
c) organo phosphate group.
d) none of the above.

Correct responses to the questions.

1.d); 2. d); 3. c); 4. a); 5 b); 6 b); 7. a); 8. a); 9 b); 10. b); 11. a); 12. a); 13. c); 14. d); 15. b); 16. a); 17. a); 18. a); 19. b); 20. b); 21. c).

Appendix I

Plant Protection and Surveillance Unit: Data Sheet
ICRISAT - Farm and Engineering Services Program

Field No : ______________ **Scientist concerned:** ______________

Area: ______________ **Name of observer:** ______________

Date : ______________

Sorghum

No. of plants with pests

Sl. no	No. of plants examined	Shoot fly		Stem borer	Mythimna	Shoot bugs	Midge	Aphids	Head bugs	*Helicoverpa*	Others
		Egg	Dead-heart								
1											
2											
3											
4											

Pearl Millet

No. of plants with insects

Sl. no.	No. of plants examined	Wireworm	Stem borer	Agrotis	Mythimna	Headbugs	*Helicoverpa*			Earhead bugs	Others
							1	2	3		
1											
2											
3											
4											

Chickpea

No. of plants with insects plant^{-1}

Sl. no.	No. of plants examined	*Helicoverpa*			Cutworm	Semilooper	Whitegrubs	Aphids	Others
		1	2	3					
1									
2									
3									
4									

Plant Protection and Surveillance Unit: Data Sheet
ICRISAT - Farm and Engineering Services Program

Field No: ________ **Scientist concerned:** ________

Area: ________ **Name of observer:** ________

Date: ________

Pigeonpea Flowering Stage

No. of insects plants^{-1}

Sl. No.	No. of plants examined	*Helicoverpa*		Leaf weber	Exelastls		Lampides		Blister beetles	Others
		Egg	Larvae		Egg	Larvae	Egg	Larvae		
1										
2										
3										
4										
5										

Groundnut

No. of plants with insects/no. of plants (meter row)$^{-1}$

Sl. No.	Thrips/terminal fold *Frankliniella, Scirto thrips*	*Helicoverpa* larvae			Spodoptera	Aphids	Leaf miner	Others
		1	2	3				
1								
2								
3								
4								
5								

Surveillance Samples, Area Covered Person^{-1} Day^{-1}, Number of Samples ha^{-1}, and Insect Pest to be Sampled.

Crop	Area (ha)$^{-1}$ person^{-1}	Samples ha^{-1}	Pests surveyed[1]	Remarks
Sorghum	10-12	20	Sfly, STBR, MY, HLLA, MI, HEBU, MIT	10 plants site^{-1}
Millet	10-12	20	WW, STBR, MY. SHBU, HLLA	-do-
Pigeonpea (Veg)	6	20	WW, Aphids, Weevils, HLLA, Cowbugs	1 plant site^{-1}
Pigeonpea (Flo.)	5	10-15	HLLA, HLEG, EXL, BBF, LW	-do-
Groundnut	5	20 m row ha^{-1}	Thrips, SPOD, HLLA, LM, Aphids, Jassids	4 m rows at 5 places

1 Sfly = Shoot fly, STBR = Stem borer, MY = Mythimna, MIT = Mites. HEBU = Headbug, HLLA = *Helicoverpa* larva, MI = Midge, HLEG = *Helicoverpa* egg, EXL = Exelastis, BBF = Blue butterfly, SPOD = Spodoptera, LW = Leaf webber, LM = Leafminer, WW = Wireworm.

Economic Threshold Levels

Growth stage	Plant type	Pest	Thresholds for action under degree of protection			Control measure and dosage	Remarks
			Intensive	Research	Economic		
Crop: Pigeonpea							
Vegetative	Short, extra short, medium and long duration (all types)	Leaf webber	40-50% plants with webs	No action	No action	Nuvan + dimethoate	15 days after germination mixture of contact + systemic insecticide (whenever the threshold is attained).
		Aphids	More than 5% plants infested	More than 5% plants infested	No action	Dimethoate 0.4 L a.i. ha^{-1} or Malathion 0.5 L a.i. ha^{-1}	
		Hairy caterpillar	Any level of infestation	1 larva $plant^{-1}$	No action	Hand picking	
		Helicoverpa	If heavy infestation is noticed	No action	No action	Contact insecticide	Occasionally a heavy infestation before flowering can occur.
Budding and flowering stage	Short duration and extra-short duration	*Helicoverpa* and Maruca	1 egg $(10\ plants)^{-1}$ or 1 larva $(10\ plants)^{-1}$	1 larva $(2\ plants)^{-1}$ or 1 egg $(2\ plants)^{-1}$	1 larva $plant^{-1}$ or 1 egg $plant^{-1}$	Pesticide and their rotation to be provided by NJA	
	Medium duration	*Helicoverpa* and Maruca	1 egg $(2\ plants)^{-1}$ or 1 larva $(2\ plants)^{-1}$	1 egg or 1 larva $(2\ plants)^{-1}$	2 eggs or 2 larva $plant^{-1}$	Pesticide and their rotation to be provided by NJA	
	Long duration	*Helicoverpa* and Maruca	-do-	-do-	-do-	Levels not provided	Insecticides as per medium duration, for intensive protection minimum four sprays required.

Growth stage	Plant type	Pest	Thresholds for action under degree of protection			Control measure and dosage	Remarks
			intensive	Research	Economic		
	Short duration, medium duration, and long duration	Exelastis	More than 1 larva plant⁻¹	More than 2 larvae plant⁻¹	More than 4 larvae plant⁻¹	Dimethoate or Monocrotophos	As least you then have a 2nd option rather than rely on one chemical.
		Pod fly	If more than 5% of developing pods are infested.	If more than 10% of developing pods are infested.	If more than 20% of developing pods are infested.	Dimethoate 0.4 L a.i. ha⁻¹ or Monocrotophos.	This depends on destructive sampling if permitted.
		Blister beetles	Less than 10 beetles in a plot.	< 25 beetles in a plot.	On heavy infestation.	Handpick	
		Bugs	5-10% plants infested.	20-25% plants infested.	No action.	Dimethoate	
		Thrips	20-25 thrips flower⁻¹.	No action	No action.	Dimethoate	Thrips infestation can occur in some patches so spot treatment is required.

Remarks: Short and extra short varieties are most susceptible to Helicoverpa. Pyrethroid should be sprayed during peak flowering when infestation is high to obtain maximum kill. Lannate should be sprayed if other pesticide are in effective

Growth stage	Pest	Thresholds for action under degree of protection			Control measure and dosage	Remarks
		Intensive	Research	Economic		
Crop: Groundnut						
20 DAE	Thrips		5 thrips T.fold^{-1}		Spray dimethoate 200-250 mL a.i. ha^{-1}	@ 220-275 L of spray fluid ha^{-1}.
30 DAE	Leafminer		5 miners plant^{-1}		Spray[1] DM-200-250 mL a.i. ha^{-1}, Mono 300 mL a.i. ha^{-1}	-do-
45 DAE	-do-		10 miners plant^{-1}		-do-	-do-
>50 DAE	-do-		15 miners plant^{-1}		-do-	-do-
40 DAE	Spodoptera and all other caterpillars		20-25% defoliation		Spray Endosulfan 400 mL a.i. ha^{-1} Monocrotophos 300 mL a.i. ha^{-1} Fenvalerate 50-80 mL a.i. ha^{-1} Lannate 250 mL a.i. ha^{-1}	-do-
Seedling stage to 30 DAE	Jassids		5-10 jassids plant^{-1}		Spray dimethoate 200-250 mL a.i. ha^{-1} Monocrotophos 300 mL a.i. ha^{-1}	-do-

1 Monocrotophos
Fenvalerate
Dimethoate — These chemicals need to be rotated in a sequence - OP. Cyclo. Carbomate. and Pyrethroid.
Lannate
Endosulfan

Remarks Only crossing block fields will be under intensive protection.

Growth stage	Pest	Thresholds for action under degree of protection			Control measure	Dosage	Remarks
		Intensive	Research	Economic			
Crop: Sorghum							
Early rainy season	Shoot fly	-	-	-	No Carbofuran		
After 1st July 5-7 days	Shoot fly	>5% egg and deadhearts	20% dead hearts before thinning	30% deadhearts before thinning	Carbofuran 3G or Phorate 10G Granules, Endosulfan	40 kg ha^{-1} 1 L 100^{-1} L of water	Carbofuran or Phorate while sowing (soil application). Foliar spray.
20 days old	Stemborer	Leaf damage or DH >5%	Leaf damage or DH >10%	Leaf damage or DH >25%	Endosulfan 35% EC Carbofuran 3G	1 L 100^{-1} L 2-3 g whorl^{-1}	
45 days	Mythimna and *Spodoptera*	One larva plant^{-1} or 10% leaf damage	Leaf damage seen on 20% of plants	Leaf damage on 40% of plants before heading	Endosulfan 35% EC	1 L 100^{-1} L of water	Hand picking of *Spodoptera* egg masses.
	Mites	Mite colonies and leaf yellowing on 5% of plants	10%	25%	Dimethoate 30 EC or Dicofol 18.5 EC	0.5 L 100^{-1} L 1 L 100^{-1} L	
Before 60 days	Shootbugs	If shootbugs or damage seen on 1% plants	If damage or bugs infestation at 20%	If damage or bugs infestation exceeds 30%	Endosulfan 35EC	1 L 100^{-1} L	
60 days	Aphids	If plants with aphids >5% at 28 days or 20% at 60 days	If aphid infestation exceeds 30% at 28 days or 50% at 50 days	If aphid infestation >50% by 50 days. Do not spray if predators present	Dimethoate 30 EC or Malathion 50 EC	0.5 L 100^{-1} L 0.5 L 100^{-1} L	
	Earhead bugs	2-3 adult or 10 nymphs head^{-1}	5 adults or 20 nymphs head^{-1}	10 adults or 50 nymphs head^{-1}	Carbaryl 50WP or Endosulfan 35EC	1 kg 100^{-1} L 1 L 100^{-1} L	Blueboy -do-

Growth stage	Pest	Thresholds for action under degree of protection			Control measure	Dosage	Remarks
		Intensive	Research	Economic			
	Helicoverpa	1 medium to large size larvae 10^{-1} heads	5 medium to large size 1 larvae 10^{-1} heads	No spraying	Endosulfan 35EC	1 L 100^{-1} L	
	Midge	1 midge fly $panicle^{-1}$	2-3 midge flies $panicle^{-1}$	5-6 midge flies $panicle^{-1}$	Carbaryl 50% WP	1 kg 100^{-1} L	
	Ants and termites	Treat nests before sowing	Treat nests before sowing	No spraying	Lindane 20EC	Bait with treated seed 10 mL Lindane 40 mL water kg^{-1} seed	

After 1st July. Carbofuran to be applied in all categories of protection. Other chemicals such as fenverlerate cypermethrin. For shootfly 20% DH under research protection seem on higher side. Use of Dimethoate would be better against shoot bugs. Level of shoot bugs under intensive protection very low. More problem in post rainy season crop. Thus number of sprays will be high.

Growth stage	Pest	Thresholds for action under degree of protection			Control measure	Dosage	Remarks
		Intensive	Research	Economic			
Crop: Chickpea							
Vegetative stage	White grubs, termites, and *Agrotis*	At vegetative stage, if >2% plant damaged.	>5% plant damage.	No spraying	Soil drenching of Lindane 20%EC BHC 10%	1 L 100^{-1} water 20 kg ha^{-1} incorporated in soil	
-do-	*Helicoverpa* and *Spodoptera*	If larvae or damage affects >20% plants	If larvae or damage exceeds 50% of plants	No spraying	Spray Endosulfan 35% or Quinalphos 25EC	0.7 L a.i. ha^{-1}	
Flowering stage	-do-	If average of more than one egg or larva (5 plants)$^{-1}$	If average of one egg or one larva (2 plants)$^{-1}$	If average of >1 larvae $plant^{-1}$	-do-	-do-	
Crop: Millet							
	Wireworm and *Agrotis*	If damage on 2% plants	If more than 10 plants effected prior to thinning or 5% after thinning	No treatment	Carbofuran 3G Endosulfan 35EC	40 kg ha^{-1} 2 L ha^{-1}	Soil application, drenching in soil.
	White grub	-do-	-do-	-do-	Lindane 5% or BHC 5% Dust		Spot treatment @ 50 kg ha^{-1} spot on soil 1 L (150 L of water)$^{-1}$
	Mythimna and *Spodoptera*	One larvae $plant^{-1}$ 10% leaf damage	Leaf damage 20% of plants	Leaf damage 40% of plant before heading	Endosulfan 35EC	1 L (100 L)$^{-1}$	
	Helicoverpa	If more than 2% of heads have larvae	If 15% or more have larvae	No spraying	Endosulfan 35EC	1 L (100 L water)$^{-1}$	
	Hairy caterpillar	If larvae on 1% or more plants	If 5% or more plants have larvae	If 10% or more plants have larvae			Hand pick with gloves.

List and Classification of Approved Pesticides (Common names)

Name ot Pesticide	Action	Class
Acephate	Insecticide	Organophosphorus
Acrolein	Aquatic herbicide	Other organic
Acrylonitrile	Fumigant	Other organic
Actellic	Insecticide	Organophosphorus
Afugan	Systemic tungicide	Organophosphorus
Alachlor	Herbicide	Carbamate
Aldicarb	Systemic insecticide, acaricide, nematicide	Carbamate
Aldrin	Insecticide	Organochlorine
Allethrin	Insecticide	Pyrethroid
Aluminum phosphide	Rodenticide	Inorganic
Amidithion	Systemic insecticide, Acaricide	Organophosphorus
Amiton	Insecticide, acaricide	Organophosphorus
Amitraz	Insecticide, acaricide	Other organic
Amitrole	Systemic herbicide	Triazole
Ammonium sulfamate	Herbicide	Other organic
Antu	Rodenticide	Thiourea
Aramite	Insecticide, Acaricide	Other organic
Asulam	Herbicide	Carbamate
Atrazine	Herbicide	Triazine
Aureotungin	Fungicide	Other organic
Azinphos-ethyl	Insecticide	Organophosphorus
Barban	Herbicide	Other organic
Barium carbonate	Rodenticide	Inorganic
Barium fluoro silicate	Insecticide	Inorganic
Barium polysulfide	Fungicide, acaricide	Inorganic
Basalin	Herbicide	Other organic
Bendiocarb	Herbicide	Thiocarbamate
Benodanil	Fungicide	Other organic

Benomyl	Systemic fungicide	Carbamate
Bensulide	Herbicide	Organophosphorus
Bentazon	Herbicide	Other organic
Benthiocarb	Herbicide	Thiocarbamate
Benzoyl prop ethyl	Herbicide	Other organic
BHC	Insecticide	Organochlorine
Binapacryl	Acaricide, Fungicide	Other organic
Bis-dimethyl (amino) fluorophosphine oxide	Systemic insecticide, Acaricide	Other organic
Bromacil	Herbicide	Uracil
Bromadiolone	Rodenticide	Other organic
Bromophos	Insecticide	Organophosphorus
Bromophos-ethyl	Insecticide, acaricide	Organophosphorus
Bromoxynil	Herbicide	Other organic
Brompyrazon	Herbicide	Other organic
Brozone	Fumigant	Other organic
Bufencarb	Insecticide	Carbamate
Butachlor	Herbicide	Carbamate
Butrizol	Fungicide	Other organic
Buturon	Herbicide	Urea
Butylate	Herbicide	Thiocarbamate
Cadmium based compounds	Fungicide	Inorganic
Calcium arsenate	Insecticide, herbicide	Inorganic
Calcium cyanide	Fumigant	Inorganic
Campogran M	Fungicide	Dithio carbamate
Captafol	Fungicide	Other organic
Captan	Fungicide	Other organic
Carbaryl	Insecticide	Carbamate
Carbendazim	Fungicide	Carbamate
Carboturan	Insecticide	Carbamate
Carbon disulphide	Fumigant	Organic
Carbon tetrachloride	Fumigant	Organic
Carbophenothion	Insecticide, acaricide	Organophosphorus
Carboxin	Fungicide	Carbamate

Cartap	Insecticide	Thiocarbamate
Chinomethionate	Insecticide, acaricide fungicide	Other organic
Chloramben	Herbicide	Organochlorine
Chlorbufam	Herbicide	Carbamate
Chlordane	Insecticide	Organochlorine
Chlorfenvinphos	Insecticide, acaricide	Organophosphorus
Chlrofersulfide	Acaricide	Organochlorine
Chlormequat chloride	Plant growth regulator	Other organic
Chlorbenside	Acaricide	Organochlorine
Chlorbenzilate	Acaricide	Organochlorine
Chlorobis (ethylamino) triazine	Herbicide	Triazine
Chlorfenoc	Herbicide	Organochlorine
Chlorofenson	Acaricide	Organochlorine
Chloro-I P C	Herbicide	Carbamate
Chloroneb	Fungicide	Organochlorine
Chloropicrin	Insecticide, fumigant	Other organic
Chloroxuron	Herbicide	Urea
Chlorpropane	Fumigant	Organochlorine
Chlorthion	Insecticide	Organophosphorus
Chlorpropham (CIPC)	Herbicide	Carbamate
Chlorophacinone	Rodenticide	Other organic
Chlorpyrifos	Insecticide	Organophosphorus
Citicide	Insecticide	Organochlorine
Clonitralide	Molluscicide	Other organic
Copper arsenate	Insecticide, fungicide	Inorganic
Copper cyanide	Fumigant	Inorganic
Copper hydroxide	Fungicide	Inorganic
Copper naphthenate	Fungicide	Other organic
Copper oxychloride	Fungicide	Inorganic
Copper sulfate	Fungicide	Inorganic
Coumachlor	Rodenticide	Other organic
Coumafuryl	Rodenticide	Other organic
Coumaphos	Insecticide	Organophosphorus

Coumatetralyl	Rodenticide	Other organic
Coyden	Herbicide	Other organic
Cuprous oxide	Fungicide	Inorganic
Cyanazine	Herbicide	Triazine
Cycloate	Herbicide	Thiocarbamate
Cyclomorph	Fungicide	Other organic
Cycluron	Herbicide	Urea
Cypermethrin	Insecticide	Pyrethroid
Cytrolane	Insecticide	Organophosphorus
2,4-D	Herbicide	Chlorophenoxy
Dalapon	Herbicide	Organochlorine
2,4-DB	Herbicide	Chlorophenoxy
D-D Mixture	Fumigant	Organochlorine
Decamethrin	Insecticide	Pyrethroid
Decarbofuran	Insecticide	Carbamate
Demeton-0	Insecticide, acaricide	Organophosphorus
Demeton-S	Insecticide, acaricide	Organophosphorus
Diazinon	Insecticide, nematicide	Organophosphorus
Dibrom	Insecticide, acaricide	Organophosphorus
Dibromochloro-propane	Fumigant	Organochlorine
Dicamba	Herbicide	Organochlorine
Dichlobenil	Herbicide	Organochlorine
Dichlofenthion	Insecticide	Organophosphorus
Dichlone	Fungicide	Organochlorine
Dichloro diphenyl dichloro ethane	Insecticide	Organochlorine
Dichloro diphenyl trichloro ethane	Insecticide	Organochlorine
Dichlorovos	Insecticide	Organophosphorus
Dichlorophen	Fungicide	Organochlorine
Dichloropropane	Fungicide	Organochlorine
Diclofop-methyl	Herbicide	Chlorophenoxy
Dicloran	Fungicide	Organochlorine
Dicofol	Acaricide	Organochlorine
Dicrotophos	Insecticide, nematicide	Organophosphorus

Dieldrin	Insecticide	Organochlorine
Diethyl toluamide	Insect repellant	Other organic
Ditenphos	Insecticide	Organophosphorus
Dikar	Fungicide, herbicide	Carbamate
Dimas	Herbicide	Other organic
Dimethoate	Insecticide, acaricide	Organophosphorus
Dinobuton	Acaricide, fungicide	Carbamate
Dinocap	Fungicide, acaricide	Dinitrophenol
Dinoseb	Fungicide	Nitrophenol
Dinoseb acetate	Herbicide	Nitrophenol
Dioxathion	Insecticide, acaricide	Organophosphorus
Diphacinone	Rodenticide	Other organic
Diphenamid	Herbicide	Carbamate
Disodium methanearsonate	Herbicide	Other organic
Disulfoton	Insecticide, acaricide	Organophosphorus
Dithianon	Fungicide	Other organic
Diuron	Herbicide	Urea
DMPA	Insecticide	Organophosphorus
DNOC	Insecticide, herbicide, fungicide	Nitrophenol
Dodemorph	Fungicide	Other organic
Dodine	Fungicide	Urea
Dusting sulfur	Fungicide	Inorganic
EDCT-mixture	Fumigant	Organochlorine
Edifenphos	Fungicide	Organophosphorus
Endosulfan	Insecticide, acaricide	Organochlorine
Endothal	Herbicide	Other organic
Endrin	Insecticide	Organochlorine
EPTC	Herbicide	Thiocarbamate
Erbon	Herbicide	Organochlorine
Ethephon	Plant growth regulator	Organophosphorus
Ethion	Insecticide, acaricide	Organophosphorus
Ethoprophos	Insecticide, nematicide	Organophosphorus
Ethoxy ethyl mercury chloride	Fungicide	Organo mercurial

Ethylene di bromide	Fumigant	Other organic
Ethylene di chloride	Fumigant, insecticide	Other organic
Ethyl tormate	Fumigant	Other organic
Ethyl mercury chloride	Fungicide	Organochlorine
Ethyl mercury phosphate	Seed treatment	Organophosphorus
Etrimfos	Insecticide	Organophosphorus
Fenazaflor	Insecticide, acaricide	Organochlorine
Fenfuram	Fungicide	Carbamate
Fenitrothion	Insecticide, acaricide	Organophosphorus
Fenson	Acaricide	Organochlorine
Fensulfythion	Insecticide	Organophosphorus
Fenthion	Insecticide	Organophosphorus
Fentin chloride	Fungicide	Organochlorine
Fentin acetate	Fungicide	Other organic
Fentin hydroxide	Fungicide	Other organic
Fenvalerate	Insecticide	Pyrethroid
Fluchloralin	Herbicide	Other organic
Fluometuron	Herbicide	Urea
Ferbam	Fungicide	Dithiocarbamate
Folex	Cotton defoliant	Organophosphorus
Fonofos	Insecticide	Organophosphorus
Formothion	Insecticide, acaricide	Organophosphorus
Fosethyl aluminum	Fungicide	Other organic
Fthalide	Fungicide	Organochlorine
Fujition	Insecticide	Organophosphorus
Gibberellic acid	Plant growth regulator	Other organic
Glyodin	Fungicide, acaricide	Other organic
Glyphosine	Chemical ripener	Organophosphorus
Guazatine	Fungicide	Other organic
Gusathion-A	Insecticide	Organophosphorus
Heptachlor	Insecticide	Organochlorine
Herban	Herbicide	Urea
Hetp (HETP)	Insecticide	Organophosphorus

Hexachlorobenzene	Seed protectant	Organochlorine
Hydrogen cyanide	Fumigant	Inorganic
Hydrogenphosphide	Fumigant	Inorganic
Indol-3-ylacetic acid	Plant growth regulator	Other organic
Indole butyric acid	Plant growth regulator	Other organic
Ioxynil	Herbicide	Other organic
Isobenzan	Insecticide	Organochlorine
Isofenphos	Insecticide	Organophosphorus
Isoproturon	Herbicide	Urea
Kitazin (IBP)	Fungicide	Organophosphorus
Lead arsenate	Insecticide	Inorganic
Lenacil	Herbicide	Uracil
Leptophos	Insecticide	Organophosphorus
Lime sulfur	Fungicide, insecticide	Inorganic
Lindane	Insecticide	Organochlorine
Linuron	Herbicide	Urea
Lucel	Fungicide	Organochlorine
Mg. phosphide	Fumigant	Inorganic
Malathion	Insecticide	Organophosphorus
Maleic hydrazide	Growth retardant	Other organic
Maneb	Fungicide	Dithiocarbamate
Mancozeb	Fungicide	Dithiocarbamate
Manuron	Herbicide	Urea
Metribuzin	Herbicide	Triazine
MCPA	Herbicide	Chlorophenoxy
MCPB	Herbicide	Chlorophenoxy
Menazon	Aphicide	Organophosphorus
Mercuric chloride	Fungicide, insecticide	Organo mercury
Metabromuron	Herbicide	Urea
Metalaxyl	Fungicide	Other organic
Metaldehyde	Molluscicide	Other organic
Metasystox	Insecticide, acaricide	Organophosphorus
Methamidophos	Insecticide, acaricide	Organophosphorus

Metham sodium	Fungicide, herbicide	Dithiocarbamate
Methomyl	Insecticide	Thiocarbamate
Methoxychlor	Insecticide	Organochlorine
Methoxy ethyl mercury chloride	Fungicide	Organo mercury
Methyl bromide	Fumigant	Other organic
Methyl-demeton	Insecticide, acaricide	Organophosphorus
Methyl mercury chloride	Seed treatment	Organo mercur
Methyl metiram	Fungicide	Dithiocarbamate
Methyl parathion	Insecticide	Organophosphorus
Metiram	Fungicide	Dithiocarbamate
Metoxuron	Herbicide	Urea
Mevinphos	Insecticide, acaricide	Organophosphorus
Mipsin	Insecticide	Carbamate
Molinate	Herbicide	Thiocarbamate
Monocrotophos	Insecticide, acaricide	Organophosphorus
Monolinuron	Herbicide	Urea
Monosodium methane arsonate	Herbicide	Other organic
Nabam	Fungicide	Dithiocarbamate
Naled	Insecticide, acaricide	Organophosphorus
Naphthylacetic acid	Plant growth regulator	Other organic
Neburon	Herbicide	Urea
Nickel chloride	Fungicide	Inorganic
Nicotine sulfate	Insecticide	Other organic
Nitrofen	Herbicide	Nitrophenol
Octamethylpyrophospho-ramide	Insecticide	Organophosphorus
Omethoate	Insecticide, acaricide	Organophosphorus
Oxadiazon	Herbicide	Other organic
Oxycarboxin	Fungicide	Carbamate
Oxyfluorfen	Herbicide	Nitrophenoxy
Paradichlorobenzene	Fumigant	Organochlorine
Paraquat	Herbicide	Other organic
Parathion	Insecticide	Organophosphorus
Paris green	Insecticide	Inorganic

Pebulate	Herbicide	Thiocarbamate
Pendimethalin	Herbicide	Other organic
Pentachloroniiro benzene	Fungicide	Chlorophenolor nitrophenol
Pentachlorophenol	Detoliant/Molluscicide	Chlorophenol
Permitrin	Insecticide	Organochlorine
Phenthoate	Insecticide, acaricide	Organophosphorus
Phenyle mercury acetate	Fungicide	Organo mercury
Phenyle mercury chloride	Fungicide	Organo mercury
Phenyle mercury urea	Seed disinfectant	Organo mercury
Phorate	Insecticide	Organophosphate
Phosalone	Insecticide, acaricide	Organophosphorus
Phosdrin	Insecticide, acaricide	Organophosphorus
Phosmet	Insecticide	Organophosphorus
Phosphamidon	Insecticide	Organophosphorus
Phosphorous paste	Rodenticide	Inorganic
Phoxim	Insecticide	Organophosphorus
Picloram	Herbicide	Organochlorine
Piperonyl butoxide	Synergist	Other organic
Pival	Rodenticide	Other organic
Plictran	Acaricide	Other organic
Potassium cyanate	Fumigant	Inorganic
Pronamide	Herbicide	Carbamate
Propanil	Herbicide	Carbamate
Propargite	Acaricide	Phenoxy
Propetamphos	Insecticide	Organophosphorus
Propineb	Fungicide	Dithiocarbamate
Propoxur	Insecticide	Carbamate
Prymachlor	Herbicide	Carbamate
Pyracarbolid	Fungicide	Carbamate
Pyrazon	Herbicide	Other organic
Pyrethrin-1	Insecticide	Pyrethroid
Quinalphos	Insecticide, acaricide	Organophosphorus
Ronnel	Insecticide	Organophosphorus

Rotenone	Insecticide	Other organic
Ryaniaspeciosa	insecticide	Other organic
Scillirocide	Rodenticide	Other organic
Selex	Fungicide	Organochlorine
Simazine	Herbicide	Triazine
Sindone-A	Herbicide	Other organic
Sindone-B	Herbicide	Other organic
Sirmate	Herbicide	Carbamate
Sodium cyanide	Rodenticide	Inorganic
Sodium fluoroacetate	Rodenticide	Inorganic
Sodium fluorosilicate	Insecticide	Inorganic
Strychnine	Vertebrate poison	Other organic
Sulphoxide	Synergist	Other organic
Sulfur	Fungicide, acaricide	Inorganic
Swep	Herbicide	Carbamate
Taracid	Fungicide	Other organic
2,4,5-TB	Herbicide	Chlorophenoxy
2,4,5-T	Herbicide	Chlorophenoxy
Tecnazene	Fungicide	Organochlorine
Tedion	Acaricide	Organochlorine
Terbacil	Herbicide	Uracil
Tetraethyl pyrophosphate (TEPP)	Insecticide	Organophosphorous
Tetrachloro-p-benzoquinonoe	Insecticide	Organochlorine
Tetrachloroiso-phthalonitrile	Fungicide	Other organic
Tetrachlorvinphos	Insecticide	Organophosphorous
Tetram	Insecticide, acaricide	Organophosphorous
Tetramethrin	Herbicide	Carbamate
Thallium sulphate	Rodenticide	Inorganic
Thanite	Insecticide	Other organic
Thiabendazole	Fungicide	Other organic
Thiaclizianthion	Fungicide,herbicide	Other organic
Thiocyclamhydrogen-oxalate	Stomach poison	Other organic
Thiometon	Insecticide	Organophosphorous

Thiophanate-M	Fungicide	Thiocarbamate
Thiram	Fungicide	Dithiocarbamate
Tillam	Herbicide	Thiocarbamate
Tolyemercury acetate	Fungicide	Organo mercury
Toxaphene	Insecticide	Organochlorine
Tranid	Acaricide	Carbamate
Triaclimenfon	Fungicide	Chlorophenoxy
Triallate	Herbicide	Thiocarbamate
Trichloroacetic acid (TCA)	Herbicide	Organochlorine
Trichlorfon	Insecticide	Organophosphorous
Tridemorph	Fungicide	Other organic
Trifluralin	Herbicide	Other organic
Triforine	Fungicide	Other organic
Triometon	Insecticide	Organophosphorus
Triorthocresyl phosphate	Insecticide	Organophosphorous
Trithion	Insecticide, acaricide	Organophosphorous
Tunic	Herbicide	Other organic
Udonkor	Fungicide	Carbamate
Vamidothion	Aphicide.miticide	Organophosphorous
Vegetta	Fungicide	Thiocarbamate
Venolate	Herbicide	Thiocarbamate
Vinclozolin	Fungicide	Organochlorine
Warfarin	Rodenticide	Other organic
Zectran	Insecticide, acaricide	Carbamate
Zinc phosphide	Rodenticide	Inorganic
Zineb	Fungicide	Dithiocarbamate
Ziram	Fungicide	Dithiocarbamate

TECHNICAL GRADE PESTICIDES

Technical grade pesticides should never be used for field application for the following reasons:

* Technical grade materials do not have the right physical characteristics for general application.
* Technical grade materials are highly concentrated and hence cannot be evenly applied.
* Technical grade materials are more toxic due to high concentration levels.