PRACTICAL MANUAL

TOXICOLOGY OF INSECTICIDES

ENT 506 3(2+1)

M.Sc. (Ag) Entomology

Dr. Ankit Upadhyay
Mrs. Roshni

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Department of Entomology

College of Agriculture
Chandra Shekhar Azad University of Agriculture and Technology
Kanpur- 208002

Syllabus: Toxicology of insecticides

Practical: Insecticide formulations and mixtures; • Laboratory and field evaluation of bio-efficacy of insecticides; • Bioassay techniques; • Probit analysis; • Evaluation of insecticide toxicity; • Toxicity to beneficial insects; • Pesticide appliances; • Working out doses and concentrations of pesticides; • Procedures of residue analysis.

Name of Student .....

Roll No. .....

Session .....

Semester .....

Course Name : .....

Course No. : .....

Credit .....

Price: Rs.

CERTIFICATE

This is to certify that Mr./Miss.....ID No.....has completed the practical of course.....course No. ..... as per the syllabus of M.Sc. Agriculture ..... semester in the year.....in the respective lab/field of College.

Date: Course Teacher

CONTENTS

Practical No. 1

Objective: Study of insecticide formulations and its compatibility

Activity: Observe various insecticide formulations available in labs and describe it briefly

Observations:……………………………………………………………………………………………………

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Practical No. 2

Objective: Study quality control of pesticide formulation

Activity: Study various quality tests, precautions to be taken during sampling and disposal of pesticides

Materials required:

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Qualitytests:……

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Practical No. 3

Objective: Study of laboratory and field evaluation of bio-efficacy of insecticides

Activity: Perform lab and field evaluation of insecticides bio-efficacy

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Methodology:……

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Interpretation:……

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Practical No. 4

Objective: Study on toxicity response by beneficial insects to sub lethal insecticide dose concentration

Activity: Study toxicity response against beneficial insects

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Practical No. 5

Objective: Study of insecticidal appliance (Dusters)

Activity: Identifying and observing duster and its components and types of dusters and describing it briefly

Observations:……

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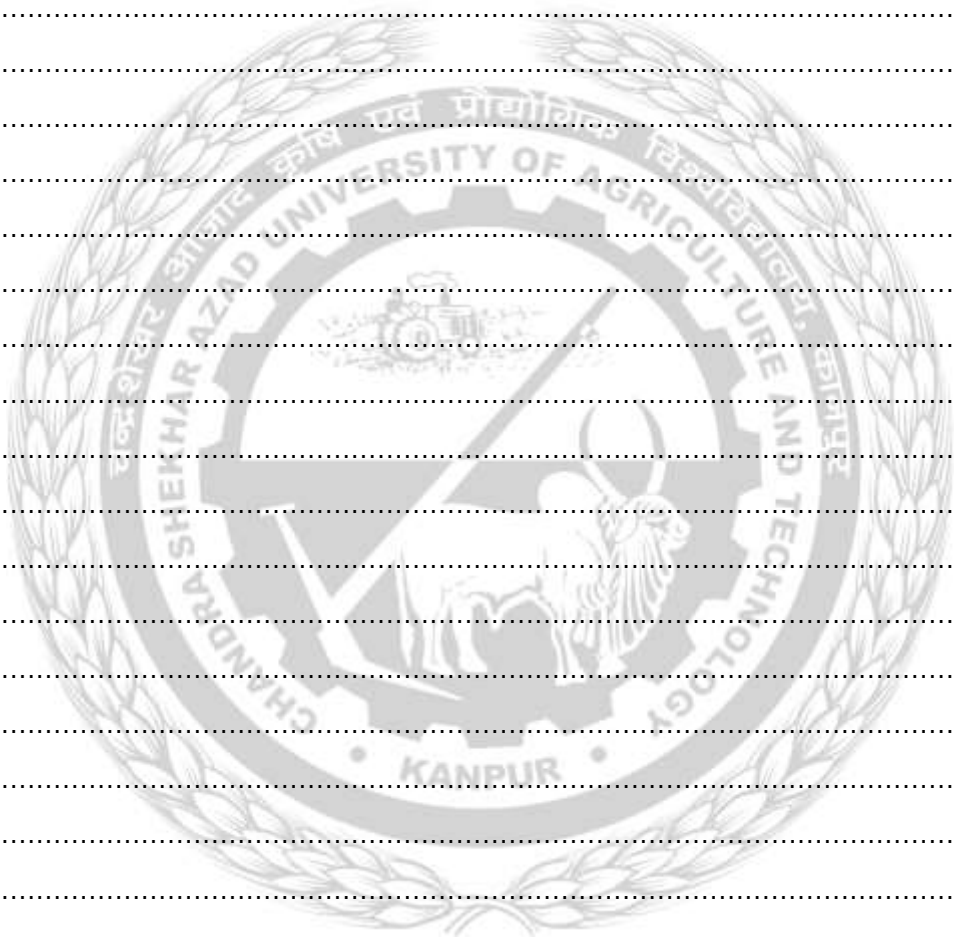

LABELLED DIAGRAM OF DUSTER

Practical No. 6

Objective: Study of Botanical insecticides

Activity: Studying various botanical insecticides and preparing few extracts like NSKE, Garlic extrat in labs from the available sources

Materials required:

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Procedure:.....

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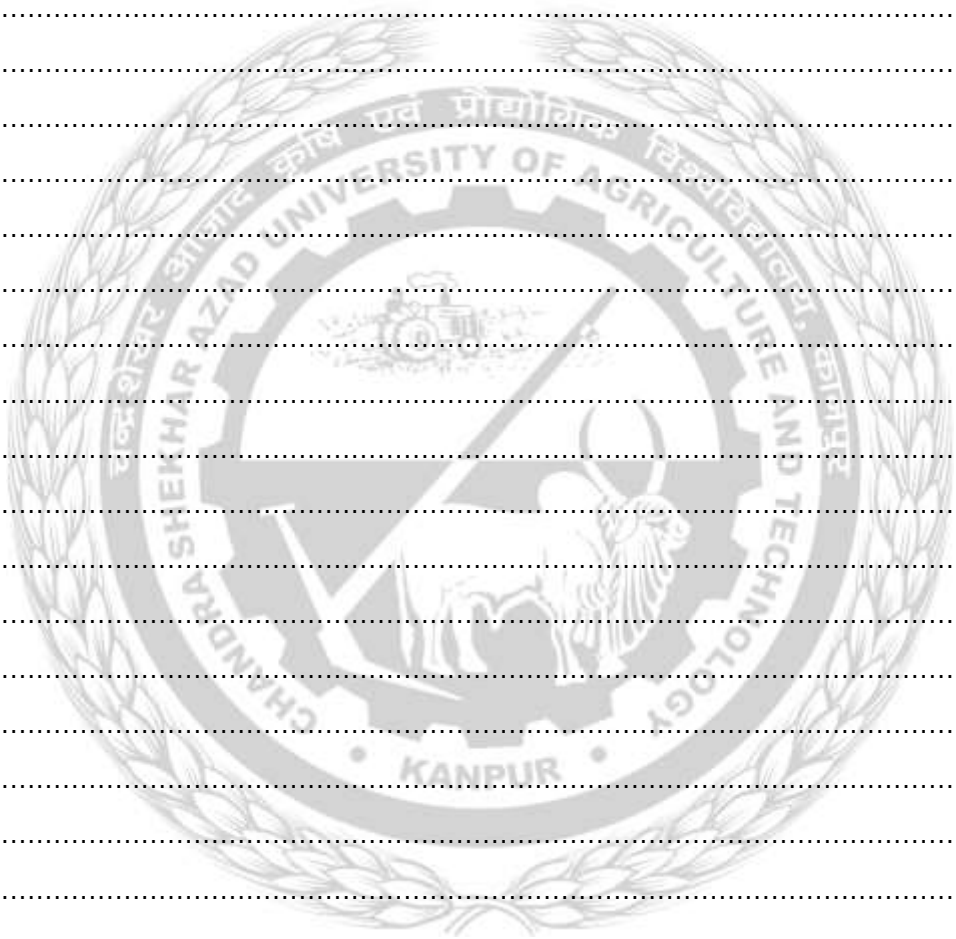
Practical No. 7

Objective: Study of factors affecting insecticidal toxicity under field conditions

Activity: Observing and study various factors affecting insecticidal toxicity before and after application

Observations:……………………………………………………………………………………………



Practical No. 8

Objective: Study of synergists and pseudosynergists

Activity: Studying different synergists and pseudosynergists and its effects on insecticide efficacy

Description:……

Practical No. 9

Objective: Study of insecticide toxicity (phytotoxicity) on crop plants

Activity: To observe symptoms appearing on crop plants due to insecticidal toxicity

Symptoms observed:……………………………………………………………………………………………

Practical No. 10

Objective: Study of insecticidal appliance (Sprayers)

Activity: Observing and describing sprayers, its types and its various components

Observations:……………………………………………………………………………………………………

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LABELLED DIAGRAM OF SPRAYER

Practical No. 11

Objective: Study of nozzles and its parts

Activity: Observe nozzle and its parts and describe it.

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Practical No. 12

Objective: Study of methods of toxicity testing (Bioassay)

Activity: Study and perform toxicity testing in labs

Materials required:……………………………………………………………………………………………

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Procedure:…………………………………………………………………………………………………

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Practical No. 13

Objective: Determination of LC50 (Probit analysis)

Activity: To determine LC50 (Probit analysis)

Materials required:……

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Procedure:……

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Result:………

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Practical No. 14

Objective: Study pesticide hazards in nature

Activity: To observe and study pesticide hazards in nature

Description:……………………………………………………………………………………………………

Practical No. 15

Objective: Study various types of insecticide resistance mechanism in insects

Activity: To study insecticide resistance types and Insecticide Resistance Management (IRM)

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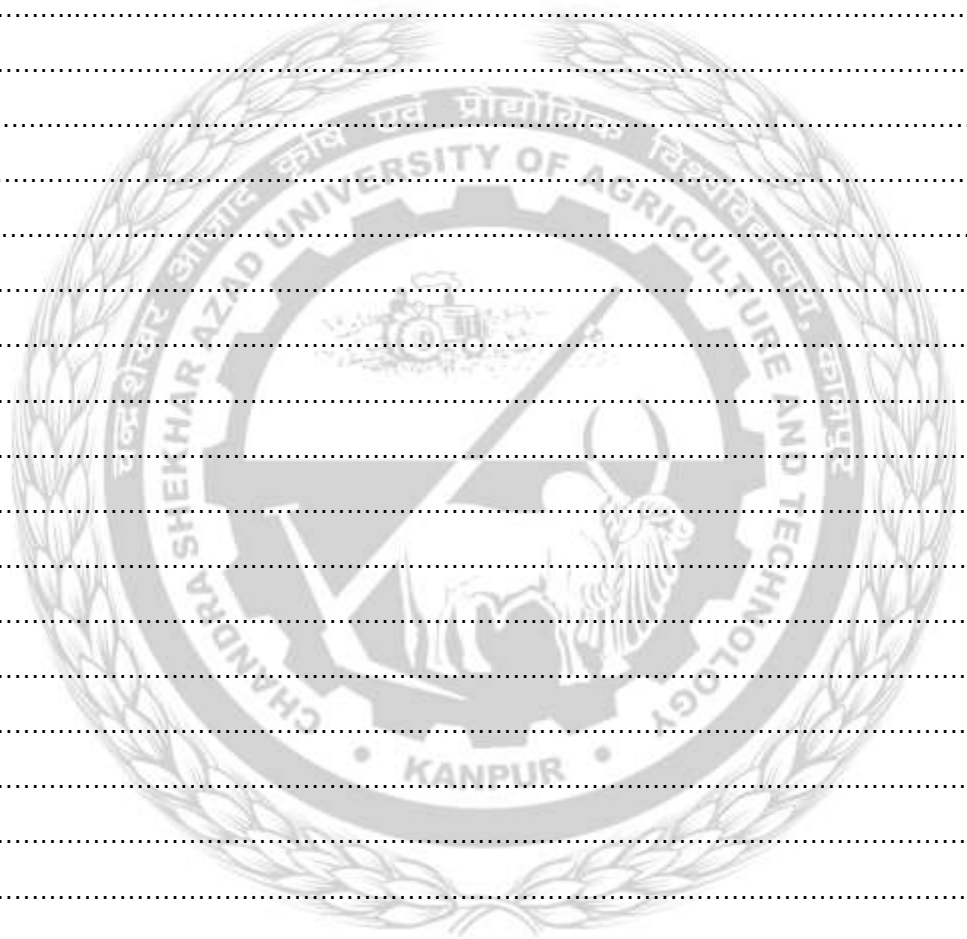


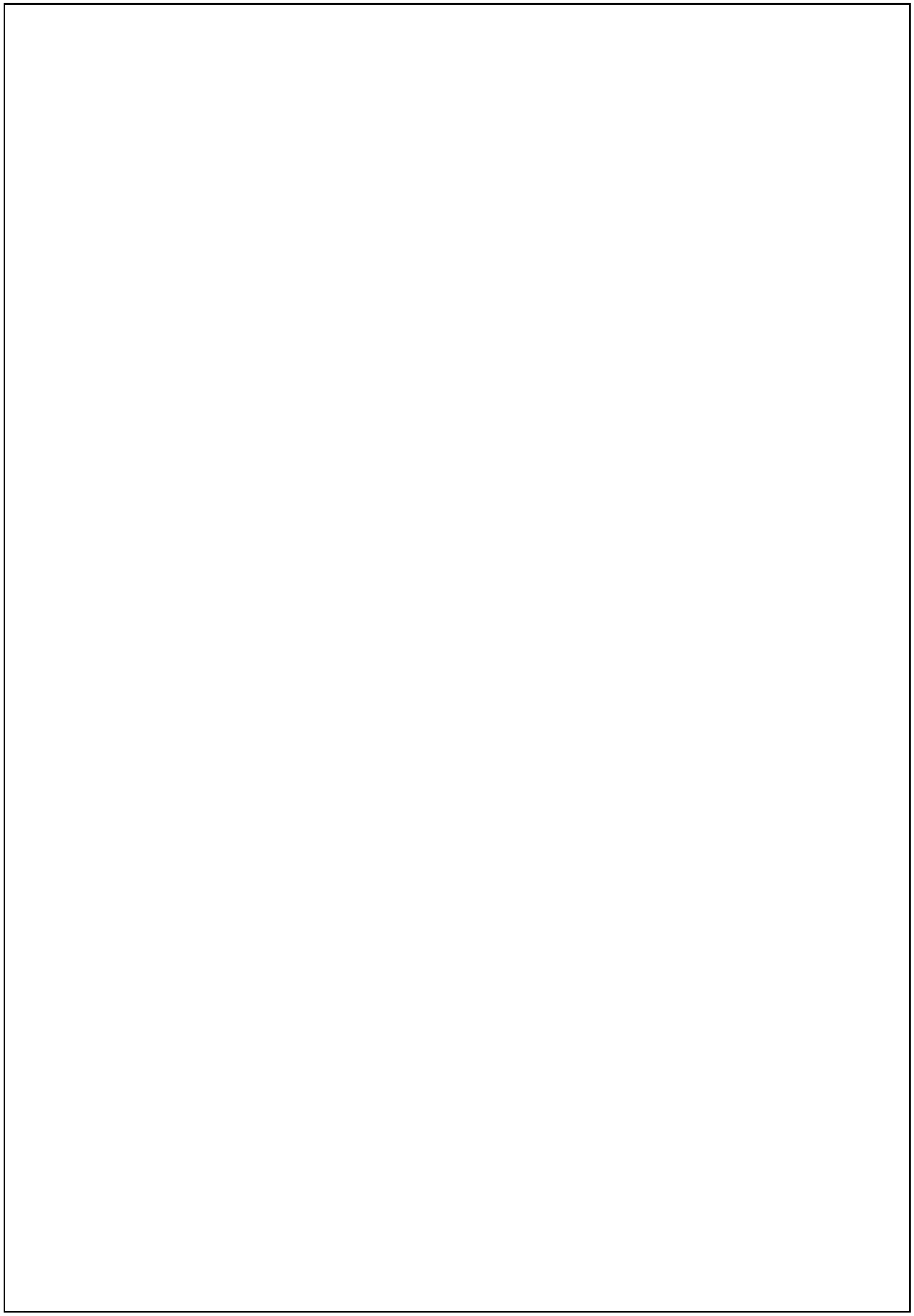
Practical No. 16

Objective: Study various toxicity labels related to agrochemicals as approved by CIB & RC

Activity: Observe toxicity labels in insecticide formulations available in your laboratory

Description:……………………………………………………………………………………………………

Diagrammatic representation with colour codes



Practical No. 17

Objective: Study basic precautions while pesticide usage

A**ctivity:** Study and observe basic precautions to be taken while spraying or dusting pesticides

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INSECTICIDE FORMULATIONS AND COMPATIBILITY

Insecticides formulation: A formulation is a mixture of ingredients prepared in a certain way and used for a specific purpose.

What are pesticide formulations? A pesticide formulation is a mixture of chemicals which effectively controls a pest. Formulating a pesticide involves processing it to improve its storage, handling, safety, application, or effectiveness.

What makes up a formulation?

- The active and inert (formerly known as inert) components are combined to create the pesticide formulation. An agent that controls plant growth, works as a desiccant, defoliant, synergist, or stabilises nitrogen is considered to be an active component. Due to changes in the active ingredient's solubility, capacity to control the pest, and ease of handling and transport, pesticides come in a wide variety of formulations.
- Active ingredients known as synergists are sometimes included in formulations. They don't itself have pesticidal capabilities, but they help another active substance kill the pest with the least amount of that ingredient. For instance, as synergists, insecticides with the active ingredient pyrethrin frequently include piperonyl butoxide or n-octyl bicycloheptane dicarboximide.
- The application of the active substance may be aided by other (or inert) compounds. Other substances, outside the active agent, which is purposefully added, can be transporters, adjuvants, solvents, or any other substance. There are many different kinds of additional ingredients, including adjuvants, which are frequently used to help the pesticide adhere to or spread out on the application surface (such as leaves), solvents, which are liquids that dissolve the active ingredient, and carriers, which are liquids or solid chemicals that are added to a pesticide product to aid in the delivery of the active ingredient. When formulations are diluted for application, other adjuvants help the mixture process.

Formulation Classification

- **Solid formulations:** Dust, wettable or water dispersible powder, granules, capsules, baits etc.
- **Liquid formulations:** Solution, emulsifiable concentrate, ultralow volume formulations, suspension etc.
- **Gaseous formulations:** Fumigant, aerosol, foams, smokes, mists and fog.

Types of insecticides formulation

Dusts: Simplest of all formulations and the easiest to apply. The technical material (active ingredient) is mixed with an inert diluents carrier such as clay, organic flour, pulverised minerals. This is the most common dust formulation sold as 2%,5%, or 10% a.i. dust. Concentration of dust formulation ranged between 0.1% and 25%. Particle size of dust particles 1-40 µ pass through 325 mesh sieve. Least effective and cause wind drift leading to poor deposit on surface. Highly toxic to beneficial insects.

Granules: 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. Consist of small pellets of the active ingredients sprayed on to clay and allowing solvents to evaporate. Size: 0.25 – 0.38 mm (20-80 mesh or 30-60 mesh. The amount of active ingredient varies from 2-10 per cent. Used mainly as systemic insecticides and can be applied on to the soil, or may be placedin the whorl of leaves depending on the nature of pest control required.

Pellets: Pellets are very similar to granules, but their manufacture is different. The active ingredient is combined with inert materials to form slurry (a thick liquid mixture). This slurry is then extruded under pressure through a die and cut at desired engths to produce a particle that is relatively uniform in size and shape. Pellets are typically used in spot applications.

Wettable Powders: Concentrated dusts containing a inert diluents (50-75% talc or clay) and a wetting agent to facilitate mixing the powder with water before spraying. Much more concentrated than dusts, containing 15 to 95 per cent active ingredient. Do not dissolve washers and rubber hoses; do not damage materials sensitive to organic solvents

Dry Flowables: Dry flowables—or water dispersible granules, as they are sometimes called—are manufactured in the same way as wettable powders except that the powder is aggregated into granular particles. They are diluted with water and applied in a spray exactly as if they were a wettable powder. Dry flowables form a suspension in the spray tank; they have basically the same advantages and disadvantages as wettable powders, with several important exceptions.

Soluble Powders: Contain a finely ground water soluble solid which dissolves readily upon the addition of water forming true solution. Do not require constant agitation and forms no precipitate. The amount of active ingredient in soluble powder ranges from 15-95% by weight; it is usually not more than 50%.

Liquid Flowables: The manufacture of liquid flowables (also called flowables or suspension concentrates) mirrors that of wettable powders—with the exception that the powder, dispersing agents, wetting agents, etc., are mixed with water before packaging. The result is a suspension requiring further dilution with water before use.

Microencapsulates: Microencapsulates consist of a solid or liquid inert (containing an active ingredient) surrounded by a plastic or starch coating. The resulting capsules can be sold as dispersible granules (dry flowables), or as a liquid formulation. Encapsulation enhances applicator safety while providing timed release of the active ingredient. Liquid forms of microencapsulates are further diluted with water and applied as sprays.

Emulsifiable Concentrates: Emulsifiable concentrates consist of an oil-soluble active ingredient dissolved in an appropriate oil-based solvent to which an emulsifying agent is added. Emulsifiable concentrates are mixed with water and applied as a spray. As their name implies, they form an emulsion in the spray tank. The emulsifying agents allow oil-soluble active ingredients to be sprayed in water as a carrier.

Solutions: Solutions (water-soluble concentrates) consist of water-soluble active ingredients dissolved in water, for sale to the applicator for further dilution prior to field application.

Miscellaneous Liquid Formulations Most liquid formulations are designed to be mixed with a carrier before application. However, some products are sold ready-to-use. (RTU). This type of formulation generally will have a low concentration of active ingredient. Typically, the container also serves as the application device. Low and ultra-low volume (ULV) concentrates used in specialty situations are frequently applied undiluted.

Aerosols and Fumigants: Aerosols and fumigants are frequently confused, yet they have very different properties and uses. Aerosols really refer to a delivery system that moves the active ingredient to the target site in the form of a mist of very small particles: solids or liquid drops. The particles can be released under pressure or produced by fog or smoke generators. Aerosols are especially useful for indoor insect control, as coverage is thorough.

Compatibility of insecticides

- Simultaneous or sequential application of insecticides, fungicides, fertilizers etc in a single cropping season advantageous
- Main reason for combinations of pesticides - saving of time, equipment wear and tear and cost of application
- Problems associated with this practice
  - ✓ Physical incompatibility (agglomeration, phase separation etc.).
  - ✓ Chemical incompatibility (degradation of active ingredient, change in pH).
  - ✓ Biological incompatibility (reduction in bioefficacy of one by other, phytotoxicity)

Consider the following before combination of pesticides is resorted to

- Do not mix two insecticides, as they will hasten the development of resistance in pests
- Do not mix the incompatible pesticides
- Do not mix the pesticides, as a matter of routine. Apply insecticide-fungicide combination only when both the target insect and plant pathogen are above ETL level.

Tests of compatibility

- Combinations may either prove phytotonic or phytotoxic sometimes
- Physical and chemical tests undertaken for testing of insecticide quality and formulations
  - ✓ Acidity and alkalinity test
  - ✓ Emulsion stability test
  - ✓ Wettability test
  - ✓ Sieve test
  - ✓ Bulk density test
  - ✓ Suspensability test

Different formulations

EC - Emulsifiable concentrate	SP- Water soluble powder
CG - Encapsulated granule	SS- Water soluble powder for seed treatment
CS - Capsule suspension	SU- Ultra-low volume suspension
DC - Dispersible concentrate	TB- Tablet
DP - Dispersible powder	FS - Flowable concentrate for seed treatment
EG - Émulsifiable granule	G - Granule
EO - Emulsion, water in oil	GC - Macrogranule
EW - Emulsion, oil in water	GL - Emulsifiable gel
ES - Emulsion for seed treatment	GP - Flo-dust
FG- Fine granule	GW - Water soluble gel
SC- Suspension concentrate	WDP- Water dispersible powder
SE- Suspo- emulsion	WG- Water dispersible granules
SG- Water soluble granule	WP- Wettable powder
SL- Soluble concentrate	WS- Water dispersible powder for slurry treatment

QUALITY CONTROL OF PESTICIDE FORMULATION

Quality control of pesticides

- The effectiveness of the pesticides in pest control programmes largely depends on the quality which in turn is the function of physico chemical properties of the active ingredients and the characteristics of the formulations
- The establishment, implementation and the monitoring of the standards of the quality of pesticides are very important facets of improved agricultural production
  - ✓ The Insecticides Act , 1968
  - ✓ The Insecticides Rules, 1971
  - ✓ The main objective of the Act is to regulate the import, manufacture, sale, transport, distribution and use of pesticides with a view to prevent risk to human beings and animals and for matters connected therewith.
  - ✓ Bureau of Indian Standards (BIS)
  - ✓ Pesticide Industries
  - ✓ Government (Central and State)

Precautions and directions for drawing samples

- Do not take sample in an exposed place.
- See that the tools used for sampling are dry and clean.
- Take necessary precautions regarding toxicity effect of samples being drawn.
- Avoid contamination during and after sampling.
- Containers receiving samples - clean, dry and air tight.
- See that the size of the container receiving samples is such that it is not completely filled by the sample.
- Seal the container with the sample air tight and furnish details regarding sampling, date of manufacture, name of the manufacturer etc.
- Store the sample in a proper place.

➢ **Scale of sampling**

- All samples of a same batch considered as one lot and samples bearing different batch numbers considered as separate lots.
- Samples from each lot are to be drawn and tested.
- The number of containers to be chosen for sampling depends on the size of the lot.

I. Physical tests

1. Dust and wettable powder formulations

- Sieving Test for particle size requirement
- Test for bulk density
- Sieve test after accelerated storage
- Compensability test
- Wettability test

2. Emulsion concentrate or emulsifiable concentrate

- Emulsion stability test
- Cold test, flash point test and heat stability test

3. Granules

- Attrition test
- Water runoff test, wet test for encapsulation and liquid holding capacity

II. Chemical tests

- Test for acidity/ alkalinity
- Active ingredient content

➢ **Disposal of pesticides**

- All unused pesticides and containers must be disposed off carefully
- Improper disposal of pesticide wastes and pesticides containers can result in incidents of animal poisoning or environmental contamination

Pesticide wastes may range as follows:

- ✓ Accidental spillage
- ✓ Left over from excess spray mixtures
- ✓ Unsold pesticide materials

- ✓ Damaged containers
- ✓ Pesticides which lost their expiry dates
- ✓ Wrong application

❖ **Disposal techniques**

1. Disposal of spilled pesticides

- Don't wash with much of water
- Sprinkle moist sand or saw dust
- Remove the contaminated soil and burry
- Wash the contaminated floor with lime or 10% sodium bicarbonate

❖ **Disposal – Burial under soil**

- Burial site must be carefully chosen
- The area should be marked out and identified such that leakage of buried pesticide will not contaminate water bodies.
- Should be buried 50 cm below
- Lime may be mixed to enhance degradation process

❖ **Disposal of containers**

- Misuse of containers should be avoided
- Empty and clean the containers before disposal
- Drain the pesticide in a vertical position for 30 seconds
- Rinse with water thrice
- Make the container unusable by puncturing and deforming
- Should be buried
- Paper and fibre container should be burnt in open air
- Herbicide containers should not be burnt in the vicinity of crops
- When burning don't respire the smoke
- Glass containers should be broken and buried

❖ **Pesticide disposal technology**

- The diversity in chemical properties of pesticides and their formulated products and the quantity and composition of pesticide wastes complicate the disposal technology
- No single treatment system can be universally applied

❖ **Chemical detoxification and disposal methods**

- Acid or base hydrolysis, oxidation, reduction or irradiation
- Other methods such as fixation, wet scrubbing, Chlorinolysis, neutralisation, precipitation, ion exchange and solvent extraction for treating industrial pesticide production plant effluents and other industrial wastes.

❖ **Physical detoxification and disposal methods**

- Incineration: This is the best method of detoxification and disposal of non-metallic toxicants.
- Ocean incineration: In this the incinerator is taken into the sea in a ship and hazardous chemicals are combusted.
- Deep well injection and ground burial and use of chemically modified peat are other physical disposal methods

❖ **Biological detoxification and disposal methods**

- Soil incorporation
- Land fills

LABORATORY AND FIELD EVALUATION OF BIO-EFFICACY OF INSECTICIDES

In Insecticides, bio-efficacy is a measure of the biological efficacy of an active ingredient of insecticides. Bio-efficacy of an insecticide is determined by the minimum dose required for maximum control of the insect pests.

Materials required: Insecticides (selected) Spryer or duster machinery, fresh water, measuring cylinder, protection kits, petri plates, insect rearing cage, data diary, pencil, antidotes etc.

Methods

Under laboratory: The objective of laboratory studies is to determine the insecticidal activity of the active ingredient and the formulated product under well-controlled conditions and against well characterized mosquito colonies for comparative purposes and, as part of research and development, to determine the suitability of the product for aircraft disinsection. The specific objectives of laboratory studies are:

- To establish dose–response relations and determine the lethal dosage (LD) of the insecticide active for 50% (LD50) and 90% (LD 90) mortality that allow assessment of the intrinsic activity of the insecticide against susceptible adult mosquito species;

- To assess the lethal concentration of the insecticide used in making disinsection aerosols, as determined by contact with insecticide spray in wind tunnel tests;
- To determine the efficacy and residual action of surface treatment products;
- To assess cross-resistance of the insecticide via known resistance mechanisms against commonly used insecticides; and
- To determine the biological efficacy of the formulated disinsection insecticide product.

Intrinsic insecticidal activity test- The objective of this test is to determine the intrinsic activity of an insecticide on a target species. This is done by topical application of an active ingredient in order to differentiate toxicity from confounding effects resulting from insect behaviour.

The relationship between dose and mortality is analysed by log-dose probit regression. Commercial software is available to estimate the LD50 and other LD values and their 95% confidence intervals (Annex 2). If mortality in the control group exceeds 20%, the test is rejected. If mortality in the control group is 0– 20%, the results with the treated samples are corrected with Abbott's formula:

$$\text{Mortility (\%)} = X - Y / 100 - Y * 100$$

Where X is the percentage mortality in the treated sample and Y the percentage mortality in the (untreated) control.

A log-probit analysis should be performed for candidate and control insecticides, and their slopes should be compared in a 2 parallelism test. The results of two series of assays are considered not significantly different if the slopes of their log-probit lines are the same (i.e. the null hypothesis of the parallelism test is not rejected) and the confidence limits of their LC50 or LD50 overlap.

Data collection - The data were recorded before (incidence of attack) or after 1st, 3rd, 7th and 10th day's chemical application of insecticides by counting the numbers of aphid per plant from 10 cm top portion of the terminal shoot on ten plants randomly selected in each treated and un-treated plots, respectively. After threshing, the seed was first weighed and cleaned separately based on yield obtained in each treated and untreated subplot. After that, check the effectiveness of the tested insecticides was assessed based on the percent reduction population of aphids. Percent reduction population was calculated using the following formula.

Present reduction = Population before spray- Population after spray/ Population before spray × 100

Biological efficacy of different pesticides against *Lipaphis erysimi*

The biological efficacy of different pesticides tested against the mustard aphid population was calculated by the given formula:

B.E. (%)= Control plot – Treated plot/ Control plot × 100

Yield: The yield was recorded after threshing first the seeds were weighed and cleaned separately based on yield obtained in each treated and un-treated subplot and then converted into kg/ha. Where one hectare is equal to 10000 m^2. The total yield was determined by the given formula:

Total yield= Weight in kg/ per plot size ×10000 ha

Statistical analysis: The data were analyzed through ANOVA by using Statistics software. The significant variances among the treatments, mean for each treatment was separated at least significant difference RBD at (0.05)
% level.

TOXICITY TO BENEFICIAL INSECTS

Objective: To study on toxicity response of beneficial insect after exposure to sub lethal concentrations of insecticides. Toxicity is the degree to which a chemical substance or a particular mixture of substances can damage an organism.

Materials required: Commercial formulation of insecticides (selected), testing insect species specimens, Sprayer or duster machinery, fresh water, measuring cylinder, protection kits, petri plates, insect rearing cage, data diary, pencil, antidotes etc.

Methods: Commercial formulation of insecticides was obtained from store of CSAUAT, Kanpur. All insecticides formulations of insecticides was used to conduct the experiment to mimic the actual application in the field. A laboratory colony was established using adults collected (*Coccinella* species) from experimental fields at CSAUAT, Kanpur. The test organisms were reared on prey (aphids) that were maintained on fresh seedlings of host plants. Eggs and pupae of predator were collected from the culture. Host seedlings and *Coccinella* species were cultivated under laboratory conditions at 25±2^{0}C, 60–90% relative humidity (RH), and a 16:8-h (light: dark) photoperiod.

Insecticidal toxicity test to *Coccinella* species at different stages

- The tube-drug film approach was employed in the microcosm toxicity experiment.
- In a clean finger tube with an inner diameter of 2.4 cm and a height of 4.3 cm, 0.7 mL of the produced insecticide liquid was precisely measured using a pipette and immediately rotated on a microrotator.
- The interior of the glass tube had a uniform coating of solutions.
- To create a homogeneous film, the film was dried at 25°C. *C. septempunctata* larvae in their first and second instars received treatments of 22.8, 15.2, 10.1, 6.8, and 4.5 mg a.i.
- L1, while those in their third and fourth instars received treatments of 33.6, 22.4, 15, 10, 6.7, and 4.4 mg a.i. L1.
- The test larvae were moved to a glass tube with a drug film.

Sub- lethal Effects on Predatory Capacity of *C. septempunctata*: The experimental sublethal doses of insecticide were chosen to be LC5, LC10, and LC20. Under sublethal exposure conditions, Coccinella larvae in their first and second instars were starved for 12 hours. Under sublethal exposure conditions, *Coccinella* larvae in their third and fourth instars were starved for 24 hours. The larvae were moved to a clean tube coated with cotton gauze to allow air exchange after starvation. The 1st and 2nd instar larvae of *Coccinella* species were offered 5 prey aphid densities (5, 10, 15, 20, and 25). Larvae in their third and fourth instars devour steadily more prey. Each larva in the third instar received five distinct prey aphid densities (30, 50, 75, 100, and 120), while the fourth instar larvae received different prey aphid densities (50, 100, 150, 200, and 250). For each treatment (including controls), three replicates were employed. After 24 hours, the number of prey consumed was counted. Under laboratory settings of 25°C, 60–90% RH, and a 16:8-h (light: dark) photoperiod, all treatments were conducted.

Effects of sublethal insecticide exposure on Coccinella species larval development: The larvae at 4 different instar stages were fed with aphid under sublethal exposure conditions for 24 h. Each treated larva was then transferred to a new tube. Sufficient aphids were offered as food during larval instar development. The remaining aphids and molting were counted at daily intervals. Six replicates were used for each treatment and continuously observed until adult emergence.

Statistical analysis: The log-probit regression analysis using SPSS 25.0 was used to calculate the LC50, or the concentration at which 50% of the test species perish. Tukey's least significant difference (LSD) tests (p 0.05) were used to compare the means. Repeated-measures analysis of variance (ANOVA) was performed to examine the overall developmental duration and survival probability for each treatment group across the various instar stages.

INSECTICIDAL APPLIANCE: DUSTERS MACHINE

DUSTERS: Duster is a machine to apply chemical in dust form. Dusters make use of air streams to carry pesticides in finely divided form on the plants.

Dusters essentially consists of 5 parts

1. Hopper and Agitator
2. Feed control
3. Fan or blower and
4. Delivery nozzle

Works of duster parts:

- **Hopper:** a container called "hopper" in the duster and a tank in the sprayer to store formulations and normally provided with an **agitator** or a stirring device to prevent caking in dust formulations or sedimentation in spray liquids.
- **Fan or Blower:** a driving force which could be a blower (fan) in the duster and a pump and blower both in the sprayer;
- .**Delivery/Delivery/ discharge nozzle/tube**: a discharge to guide the formulations out.
- A nozzle fixed at the end of the delivery tube to break (atomize) the formulations into proper-sized particles (or droplets) and also to provide proper shape to the outgoing formulation and
- Miscellaneous accessories like the strainers to filter the spray liquids, valves to maintain the flow in one direction, pressure or air-chamber to allow a continuous flow, a spray lance to regulate discharge of the flow a continuous flow, a spray lance to regulate discharge of the flow through the nozzle, a boom to increase the number of nozzles etc., which have been described and figured along with the respective appliances.

TYPES OF DUSTERS

MANUALLY OPERATED

1. **Plunger duster:** These consist of a air pump of the simple plunger type, a dust chamber. These are useful for spot application in restriction areas and for controlling ants, poultry pests and pest of farm animals.
2. **Bellows duster**: On squeezing it pufs the air that expels the dust in a small cloud. These are also used for spot treatment. Capacity 2.5kg-5.0kg.
3. **Rotary duster:** It consists basically of a blower complete with a gear box and a hopper. It can be carried in hand, shoulder mounted and belley carried type.

4. **Arial duster or crop duster:**- an aircraft is used for dusting or spraying large acreages with pesticides. Aerial spraying and dusting permit prompt coverage of large areas at the moment when application of pesticide is most effective and avoid the need for wheeled vehicles that might damage crops. The technique was greatly improved in the 1960s with the development of ultra- low-volume applicators, in which concentrated pesticides are distributed in amounts as small as 1 ounce per acre (70 grams per hectare).

POWER OPERATED

1. **Power duster:** It resembles the rotatory duster except the power to drive the blower through the gear box. Power dusters are manufactured in varieties of forms.
2. **Power take off duster:** They have a auxiliary engine. They have only one big metal hose which can be turned to direct dust in any direction. Airplane dusters have been successfully used to apply dust to both field crops and orchards.
3. **Traction duster:** Traction dusters derive their power from the turning of the land wheels. There are two types of traction dusters wheel barrow type and two wheeled trailer type. Wheel barrow type are used foe small areas and the other is for large area or field.

Desirable quality of a sprayer

A good sprayer should possess the following qualities:

- ✓ It should produce a steady stream of spray material in desired droplet size so that the plants to be treated may be covered uniformly.
- ✓ It should deliver the liquid at sufficient pressure so that the spray solution reaches all the foliage and spreads uniformly over the plant body.
- ✓ It should be light in weight yet sufficiently strong, easily workable and repairable.

Care and Maintenance of Dusters:

- Duster should be thoroughly cleaned before and after use with a suitable brush.
- The hopper should be filled with dust about half of its capacity.
- The lid of the hopper should be closed during the operation.
- In rotary dusters, the handle should be cranked at 30 to 35 revolutions per minute for efficient performance.
- Before storing the duster after use, the dust from the fan box, suction pipe and hopper should be thoroughly blown out and the agitation shaft should be profusely oiled while cranking.
- Pieces of paper, sacking and other foreign materials should be prevented from getting into the hopper.
- The agitator parts and dust feed should be occasionally checked for blockage by foreign matters.

BOTANICAL INSECTICIDES

Natural compounds called botanical pesticides work well against viruses, nematodes, bacteria, fungus, and insect pests. They are abundantly available in the environment, highly biodegradable, have a variety of mechanisms of action, are less harmful to humans, and are not pollutants. Or

One of the naturally occurring chemicals found in plants is referred to as botanical pesticides. Nature- oriented pesticides can be used as an alternative to synthetic formulations, but they are usually claimed to be more toxic to humans. Some of the most lethal carcinogenic substances, like deadly toxins, develop quickly and thrive in nature.

Major insecticides

Generic Name	Oral LD50	Dermal LD50	Signal Word
Pyrethrins	1,200-1,500	>1,800	Caution
Rotenone	60-1,500*	940-3,000	Caution
Nicotine	50-60	50	Danger
d-Limonene	>5,000	—	Caution
Linalool	2,440-3,180	3,578-8,374	Caution
Neem	13,000	—	Caution

I. **Pyrethrum and Pyrethrins**: Pyrethrum is the powdered, dried flower head of the pyrethrum is daisy, *Chrysanthemum cinerariaefolium*. Most of the world's pyrethrum crop is grown in Kenya. The term "pyrethrum" is the name for the crude flower dust itself, and the term "pyrethrins" refers to the six related insecticidal compounds that occur naturally in the crude material, the pyrethrum flowers. They are extracted from crude pyrethrum dust as a resin that is used in the manufacture of various insecticidal products. **Mode of action-** Pyrethrins exert their toxic effects by disrupting the sodium and potassium ion exchange process in insect nerve fibers and interrupting the normal transmission of nerve impulses. Pyrethrins insecticides are extremely fast acting and cause an immediate "knockdown" paralysis in insects. Despite their rapid toxic action, however, many insects are able to metabolize (break down) pyrethrins quickly. After a brief period of

paralysis, these insects may recover rather than die. To prevent insects from metabolizing pyrethrins and recovering from poisoning, most products containing pyrethrins also contain the synergist, piperonyl butoxide (PBO). Without PBO the effectiveness of pyrethrins is greatly reduced.

II. **Rotenone:** Rotenone is insecticidal compound that occurs in the roots of *Lonchocarpus* species in South America, Derris species in Asia, and several other related tropical legumes. Commercial rotenone was at one time produced from Malaysian Derris. Currently the main commercial source of rotenone is Peruvian *Lonchocarpus*, which often is referred to as cube root. **Mode of action**: Rotenone is a powerful inhibitor of cellular respiration, the process that converts nutrient compounds into energy at the cellular level. In insects rotenone exerts its toxic effects primarily on nerve and muscle cells, causing rapid cessation of feeding. Death occurs several hours to a few days after exposure. Rotenone is extremely toxic to fish, and is often used as a fish poison (piscicide) in water management programs.

III. **Nicotine:** Nicotine is a simple alkaloid derived from tobacco, *Nictiana tabacum*, and other Nicotiana species. Nicotine contitutes 2-8% of dried tobacco leaves. Insecticidal formulations generally contain nicotine in the form of 40% nicotine sulfate and are currently imported in small quantities from India. **Mode of action**: In both insects and mammals, nicotine is an extremely fast- acting nerve toxin. It competes with acetylcholine, the major neurotransmitter, by bonding to acetylcholine receptors at nerve synapses and causing uncontrolled nerve firing. This disruption of normal nerve impulse activity results in rapid failure of those body systems that depend on nervous input for proper functioning. In insects, the action of nicotine is fairly selective, and only certain types of insects are affected.

IV. **Neem:** Neem products are derived from the neem tree, Azadirachta indica,that grows in arid tropical and subtropical regions on several continents. The principle active compound in neem is azadirachtin, a bitter, complex chemical that is both a feeding deterrent and a growth regulator. Meliantriol, salannin, and many other minor components of neem ar also active in various ways. Neem products include teas and dusts made from leaves and bark, extracts from whole fruits, seeds, or seed kernels, and an oil expressed from the seed kernel. The product known as "neem oil" is more like a vegetable or horticultural oil and acts to suffocate insects. Neem and neem oil are often confused. **Mode of action:** Neem is a complex mixture of biologically active materials, and it is difficult to pinpoint the exact modes of action of various extracts or preparations. In insects, neem is most active as a feeding deterrent, but in various forms it also serves as a repellent, growth regulator, oviposition (egg deposition) suppressant, sterilant, or toxin.

V. **Citrus Oil Extracts: Limonene and Linalool:** Crude citrus oils and the refined compounds d- limonene (hereafter referred to simply as limonene) and linalool are extracted from orange and other citrus fruit peels. Limonene, a terpene, constitutes about 90% of crude citrus oil, and is purified from the oil by steam distillation. Linalool, a terpene alcohol, is found in small quantities in citrus peel and in over 200 other herbs, flowers, fruits, and woods. **Mode of action:** The modes of action of limonene and linalool in insects are not fully understood. Limonene is thought to cause an increase in the spontaneous activity of sensory nerves. This heightened activity sends spurious information to motor nerves and results in twitching, lack of coordination, and convulsions. The central nervous system may also be affected, resulting in additional stimulation of motor nerves. Massive over stimulation of motor nerves leads to rapid knockdown paralysis. Adult fleas and other insects may recover from knockdown, however, unless limonene is synergized by PBO. Linalool is also synergized by PBO. Little has been published regarding the mode of action of linalool in insects.

STANDARD PROCEDURES FOR PREPARATION AND APPLICATION OF NEEM EXTRACTS

- ✓ Select healthy neem leaves that are free from diseases.
- ✓ When storing the plant parts for future usage, make sure that they are properly dried and are stored in an airy container (never use plastic container), away from direct sunlight and moisture. Make sure that they are free from moulds before using them.
- ✓ Use utensils for the extract preparation that are not used for your food preparation drinking and cooking water containers. Clean all the utensils properly before and after use.
- ✓ Do not have direct contact with the crude extract while in the process of the preparation, and during the application.
- ✓ Make sure that you place the neem extract out of reach of children and house pets while leaving it overnight.
- ✓ Harvest all the mature and ripe fruits on the crop to be sprayed before neem application.
- ✓ Always test the plant extract formulation on a few infested plants first before going into large scale spraying. When adding soap as an emulsifier, use a potash-based one such as gun soap (Kenya).
- ✓ Wear protective clothing while applying the extract.
- ✓ Wash your hands after handling the plant extract.

DETAILED RECIPE TO PREPARE 10 LITRES OF NEEM SEED KERNEL EXTRACT (NSKE):

1. Grind 500 grams (g) of neem seed kernels in a mill or pound in a mortar.
2. Mix crushed neem seed with 10 litres of water.
3. It is necessary to use a lot of water because the active ingredients do not dissolve easily.

4. Stir the mixture well.
5. Leave to stand for at least 5 hours in a shady area.
6. Spray the neem water directly onto vegetables using a sprayer or straw brush.
7. Neem water can be stored and will remain effective for 3 to 6 days if it is kept in the dark.
8. It has been estimated that 20 to 30kg of neem seed (an average yield from 2 trees), prepared as neem water can treat 1 hectare of crop.

- **Neem seed kernel powder:** Collect neem fruits locally, remove the outer skin along with the pulp, clean the seeds and dry in shade. After a week, remove the seed coat and grind the resultant contents into fine powder. Sieve it and preserve in glass jars for further use.
- **Pongamia leaf extract:** Farmers of Karnataka collect the leaves of pungam (pongamia spp.) which grow on river sides, road sides and in forests and incorporate them in water-logged paddy fields before transplanting. The leaves get thoroughly mixed during the puddling operation, and once they mix well in the field they decay within 2 or 3 days.
- **Ipomoea leaf extract:** Clip and pool 5 Kg of fresh leaves of Ipomoea, leaving the waste materials like waste bark and dried stem. Clip the fresh leaves and make them into fine paste. Mix the paste with equal volume of water and boil. Now add little quantity of cow urine to this boiling mixture. When mixture is at one fourth of its actual volume, remove from the burner and allow it to cool for overnight. Filter the solution in the morning and repeat the washing with cow urine and make the volume to 4.5 litre. Add 250g of soap powder in 500 ml of water and mix the extract with the soap solution and use 500 ml in 10 litre of water for an acre.
- **Vitex leaf extract:** This is commonly available on the road sides. Pluck the fresh leaves, clean and chop them well using grinder and make them into paste. Soak this in 3 litre of clean, filtered cow urine for overnight. In the next day morning, stir the soaked solution and boil at 70-80°C for about 3-4 hours. Add fresh distilled water when the solution in concentrated too much, allow it to cool overnight and filter using kada cloth. Mix 150 g of soap powder in 250 ml of water and add to the filtrate. Dilute 50 ml of final solution mixture in 1 litre of water to spray.
- **Calotropis leaf extract:** Collect calotropis leaves, 1 kg with latex, clean well from impurities, chop and make them into fine paste and mix this paste with 50 l. of water and filter the suspension and spray.
- **Tinospora plant extract:** Chop vines of Tinospora cordifolia Boerl, grind into paste with water and stir thoroughly. Rice seedlings are soaked in this liquid for whole night before transplanting. About 10-15 kg of chopped vines is needed for the treatment of seedlings for planting in one hectare. This is effective against the rice green leafhopper. The vines are cut into 30 cm long pieces or tie it to couple of bamboo pole on both ends and keep them in the field. Sometimes, smaller pieces are stuffed in net type shopping bag. The bag as such is kept at the water inlet of the field. However, the vine pieces should be removed before the grain sets.
- **Jatropha plant extract:** Clean stem and leaves of Jatropha plant with pure water and grind well, soak this oily paste, 5 kg in 5 litre of cow urine for overnight and boil it for 3-4 hours in 2 litre of water. The material is concentrated to 5 litre and filtered in coarse kada cloth and the filtrate is sprayed.
- **Tobacco waster extract:** Collect the tobacco waste from the field after harvest or form shops, cut them (5 kg) into pieces and soak in cow urine of 5 litre for 7 days. Filter the suspension and mix 150 g of soap and 250 ml of water and spray @ 50 ml/litre of water.
- **Agave flesh extract:** Agave plants which grow on the road sides are cut, cleaned, chopped into pieces and then made into paste by grinding well. Soak it in pure water for 24 hour. The suspension must be mixed well and filter it using muslin cloth. About 500 ml of cow urine may also be added at every spray to 100 ml of the extract and 10 g of soap solution.
- **Garlic clove extract:** Chop clean garlic bulbs, make them into paste and soak with equal volume of kerosene and allow the mixture to stand still for overnight. Mix it and filter with fine kada cloth. Add 150 g of common soap powder to the above mix and store in a clean glass bottle.
- **Green chilli and garlic extract:** Wash destalked fresh green chillies in distilled water, make them into fine paste, mix in 10 litre of water and boil at 70-80°C till the contents are reduced to half. Chop clean garlic cloves, make them into paste and soak with equal volume of kerosene and then allow the mixture to stand still for 12-24 hours and later mix it and filter using fine kada cloth. Mix about 150 g of common soap powder with 250 ml of water and mix the above three extracts together, spray 20 ml of the extract per 1 litre of water.
- **Aqueous solution of kernels of *Melia azedarach*:** *Melia azedarach* kernels are soaked in a liter of water and boiled for half an hour and kept undisturbed for 24 hours.1 litre of cow urine is mixed with 159 g of soap powder and filtered. The filtrate is mixed with Melia azedarach kernel extract and stored for future use.
- **Nerium seed extract:** Seeds of *Nerium indicum* are collected, shade-dried for a few days, made into powder, sieved, and then soaked in water to be left undisturbed for overnight, filter with kada cloth and filtrate is sprayed.
- **Mahuva oil spray:** Mix 30 ml of the Mahuva oil and 5 g of soap with 1 litre of water for spray.

- **Fish oil rosin soap solution:** Fish oil rosin soap 1 litre is added to water and tobacco extract and soap are added. Spraying is done in morning hours.
- **Cigar end filtrate:** Boil non-filter-tipped cigarette ends or half of filters in 9 litre of water for half an hour. Strain through muslin cloth and heat the clear brown liquid with one of soft soaps till it is dissolved. Mix 1 part of brown fluid with 4 parts of water for spraying.
- **Cow dung extract:** Collect fresh cow dung, dissolve it at the rate of 100-g in 100 ml of water, filter with kada cloth and spray.
- **Neem leaf powder:** Collect fresh neem leaves, clean well to ensure free of dirt and dusts, and dry it in shade for 15 days. Then, crush the leaves to powder form and treat the seeds.
- **Adathoda leaf dust:** Collect Adathoda leaves locally, clean from impurities and shade dry for a week. Crush the shade-dried leaves into fine powder and store for future use.
- **Cannabis leaf dust:** Collect cannabis leaves, shade dry, and crush into fine powder and use.
- **Nochi leaf dust:** Collect Nochi leaves locally, shade dry for 15 days, crush into fine powder and use.
- **Tobacco leaf dust:** Dry the cured tobacco leaf in the shade, make it into fine powder and use.
- **Ipomoea leaf dust:** Collect Ipomoea leaves from the plants found on the waste lands and irrigation canals, dry for 15 days, make it into fine powder and use.
- **Tobacco dust:** Collect tobacco plant waste materials from the field as well as shops, shade-dry for about 15 days and then powder finely.
- **Neem and Datura leaf powder:** Collect Neem and Datura leaves, clean and dry them under shade. After a week, crush the dried leaves into powder and store for future use. Neem and Datura are mixed in equal amounts.
- **Turmeric powder:** Prepare Turmeric powder out of turmeric rhizome gathered from the local market and store in glass bottles.
- **Vasambu rhizome powder:** Prepare vasambu rhizome collected from the local market, into fine powder after removing its outer skin and use.
- **Rice bran and kerosene mixture:** Sieve the rice bran gathered from the rice mill to get fine particles and mix it (14 kg) thoroughly in 2 l. of kerosene and dust the mixture in the morning hours.
- **Rice and saw dust:** Rice bran and saw dust gathered from the rice mill and saw mill are used.
- **Saw dust:** 15 kg of sieved saw dust is mixed with 2 l. of kerosene and used as dust.
- **Cycas cone pieces:** The cycas cone is available in the western ghats of the Tamilnadu border at Pulayari in Tirunelveli District and Ariyankkavu in Kerala state. The male cones when become matured, emit the fragrant smell, which is insecticidal in action. These cones are cut into small pieces and kept in a bunch of wet paddy straw. This is placed on the top of stick kept in the field to the level of plant canopy. The paddy straw is continuously kept wet to enhance the odour emission.
- **Tree bark pieces:** Mix barks of various trees like *Cinnamomum zeylanicum*, and *Eucalyptus* in a ratio of 1:4 and keep the bags of paddy seeds. The barks are broken in a reasonable size and then used.
- **Common Ash:** Prepare ash from the common fire wood and dry leaves after burning, grind ad sieve to get fine powder and use.
- **Brick kiln ash:** Collect ash from brick kiln and sieve for fine particles and use.
- **Wood ash dust:** The ash is collected from the residues of fire wood and cleaned well by sieving. The fine powder thus collected is stored in separate clean containers for future use.
- **Fly ash:** Grind the lignite fly ash available from Neyveli Lignite Corporation, Neyveli into fine powder. Sieve it to get fine powder and store in glass containers for future use.
- **Sand:** River sand is sieved to fine and used in seed treatment.
- **Leaves of Dhumas (*Combretum ovalifolium* Spreng.):** Collect leaves of Dhumas, a shrub found along farm boundary and in waste lands. About 5-7 persons stand in a row and keep leaves of this plant in individual bags on their back. They start moving from one side of the field to the other in the direction of wind. In the way, they catch 1-2 bugs from the air and crush them with 2 or 3 leaves by rubbing palms of hands. Peculiar smell comes from the mixture of leaves and insects. According to user of this practiced, the pest will fly away in the direction of wind due to peculiar odour. As soon as the smell is over (or) got reduced i.e., after 2-4 min. fresh insects and leaves are crushed continuously till all the insects fly away in one direction quickly.
- **Calotropis stem scare:** The farmers remove the leaves and then split the stems of calotropis vertically into the two halves with a sickly and cut them into small pieces (10 to 15 cm long). Scatter these pieces in the field along the border

and on bunds at a distance of 2 to 3m. in such a way that their top sides remains up. The stem surface, which resembles the skin of the snake locally found is believed to scare the rats away.

- **Glyricidia rat killer:** *Glyricidia sepium*, a fast growing leguminous tree is a "rat killer". Farmers grind the bark and leaves, mix it with damp wheat or smear it on banana slice and use it for the purpose. A mixture of cereals and the leaves of Glyricidia are ground together and allowed to ferment. The fermented solution is used as bait for the rats Bunch or thorny thistle flower is tied to the ends of the beam holding food shift deters the rat by pricking them and so the rats do not try to cross over the thorns.
- **Turmeric cooked rice:** Turmeric powder-mixed cooked rice, which will be yellowish is placed in the field for infestation by the worms and the semiloopers and birds are attracted to this. They will be picked by the birds sitting on poles set in the field. Approximately 1 kg rice is needed for an acre. Small umps of the yellow coloured rice are placed in the field, at 5 m apart in early morning or late evening, this practice initiated when significant numbers of larvae begin to appear. It is repeated continuously for 2 or 3 days. The first day usually passes as a baiting day, but from the second day large number of birds, attracted by the rice, will prey upon the larvae. The food is offered in a thin dish made from the cross section of a banana leaf sheath balanced delicately on a slated, when the birds attempt to take the food, accidentally tilts and the food falls down to the ground. When the birds go for the fallen food, they find the caterpillars then and eat them too.

FACTORS AFFECTING THE INSECTICIDAL TOXICITY

Various characteristics of xenobiotic, their exposures, surrounding medium and organisms affect their toxicity. Characteristics which affect the toxicity of a chemical are considered as modifying factors.

- **The factors pertaining to the chemicals are:**

1. Physicochemical properties including the functional groups,
2. Solubility in water and organic solvents,
3. Dose/concentration,
4. Ionic characteristics
5. Translocation and biotransformation,
6. Their mode of action, and
7. Interaction with other chemicals.

- **Almost all these characteristics are dependent on the structure of compound. Factors related to the exposures are:**

1. Routes of exposure,
2. Exposure systems,
3. Exposure duration, etc.

The factors pertaining to the organisms are:

1. Type of species,
2. Sex,
3. Age,
4. Stage of the life cycle,
5. Weight and size of individual,
6. Health and nutritional status,
7. Seasonal physiological state, and
8. Acclimation of individuals.

Factors related to the organisms may also be termed as biotic modifying factors. For the sake of convenience, this chapter will be divided into following four sections:

1. **Factors pertaining to chemical**
- Chemical composition
- Dose or concentration of chemical
- Translocation of toxicant
- Biotransformation of toxicants
- Chemical interaction

2. **Factors pertaining to exposure**
- Exposure routes,
- Exposure duration, and
- Exposure system

3. **Factors pertaining to surrounding medium**
- Water temperature
- Dissolved Oxygen
- Soil-pH
- Salinity
- Water hardness
- Suspended and dissolved matter

4. **Factors pertaining to organisms**
- Test species
- Sex
- Age
- Life-stage
- Size
- Health and nutrition
- Acclimatio

SYNERGIST AND PSEUDOSYNERGIST

Synergist: also called activator or adjuvant, the term synergist is derived from the greek word synergos meaning together. Synergist are chemicals which have little or no insecticidal property of their own, but when added to an insecticide, enhance its toxicity manifold. The enhanced toxicity is greater than sum of toxicities of the two components reckoned separately to more than the additive toxicity of the two taken together. This phenomenon, first discovered in 1938, is known as synergism and the substance producing it a synergist. A substances that has the opposite effect i.e. that which reduces the toxicity of an insecticide is called an antagonist.

Example of synergist- methylene dioxyphenyl compound such as sesamine drived from the oil of sesamum indicum, piperine obtained from black peper, piperonyl cyclonene or cyclohexonone, peperonyl butoxide , peperonyl amides , propyl isome, IN 930 Terpine derivatives like thanite, terpine diacetate and pine oil

PSEUDOSYNERGIST- Certain substances increase the efficiency of pyrethrins by stabilising the droplet size of their sprays and thus ensuring better and persistant contact with the insect body achieving a better rate of killing. They are referred to as pseudosynergist. Example. Oleic acid, lubricating oils and pine oil.

Mode of action of Synergist: the mode of action of synergist not clearly understood but three possible are suggested:

- Synergist may produce three types of effect e.i. inductive and noninductive effect. Though the inductive effect, they activate their enzyme system which then enhanceds the toxicity of insecticide. This slow process taking long time to operate and therefore not usefull for synergism Non –inductive - effect are those in which synergist inhibit the enzymes that detoxify the insecticide and thus enhance the killing power of the latter
- Synergist may improve penetration of the insecticides through the insect cuticle and the nervous system. This is indicated by the fact that synergism occurs only when application of the synergist precedes that the insecticide. If the synergist is applied later than the insecticides, no synergist precedes that of insecticide.
- Synergists may be protecting the insecticide from weathering effect , thereby increasing the residual action and thus the amount of kill

PHYTOTOXICITY OF INSECTICIDE ON CROP PLANTS

PHYTOTOXICITY: Injury or affects caused by the insecticides on plants

1. Permanent- leading to the death of the effected part or whole plan
2. Temporary- which allows the plant to recover

Most insecticides show temporary / permanent phytotoxicity when applied indiscriminately at much higher conc/dose e.g.: farmers are applying insecticides as ULV sprays which are meant for application as higher volume sprays. Sometimes the solvents/diluents used may also cause phytotoxicity.

Symptoms of phytotoxicity

- Chlorosis or yellowing of leaves
- Bronzing of leaves
- Necrosis of complete plant or parts
- Scorching and Mottled leaves
- Deformation and curling of leaves
- White spots on leaves
- Burning effects on leaves
- Premature falling of leaves
- Poor germination of seeds

INSECTICIDAL APPLIANCE: SPRAYING MACHINES

SPRAYERS: Sprayer is a machine to apply fluids in the form of droplets. It helps to break the liquids into droplets for effective size for uniform application over the plants.

Components of sprayer: There are 15 components or parts of sprayers:

- Nozzle body
- Swrill plate
- Filter
- Over flow pipe
- Releif valve
- Pressure regulator
- Cut-off valve
- Spray boom
- Drop legs
- Nozzle boss
- Nozzle disc
- Nozzle cap
- Nozzle tip
- Spray lance
- Spray Gun

❖ **Types of sprayers**

1. **Manually operated:** Hand syringe, hand sprayer, knapsack sprayer, bucket sprayer, rocker sprayer
2. **Power operated**

- Stretcher sprayer
- Power take off sprayer
- Traction sprayer
- Mist blower and sprayer
- Ultra low volume sprayer
- Foot sprayer or pedal pump

NOZZLES PARTS AND ITS MODIFICATION

Nozzle: The nozzle performs four basic functions:

1. Atomizes liquid into droplets.
2. Disperses the droplets in a specific pattern.
3. Meters liquid at a certain flow rate.
4. Provides hydraulic momentum.

The Nozzle Tip is one of the most important and least expensive part of a spraying system.

Parts of a nozzle

1. Body
2. Strainer
3. Swirl plate
4. Gasket
5. Disc
6. Cap

Types of nozzle

1. **Hollow cone nozzle:** This liquid is fed into a whirl chamber through a tangential entry or through a fixed spiral passage to give a rotating motion. The liquid comes out in the form of a harrow conical sheet which then breaks up into small drops.
2. **Solid cone nozzle:** This nozzle covers the entire area at small range. The construction is similar to hollow cone nozzle with the addition of an internal jet which strikes the rotating liquid just within the orifice of discharge. The breaking of drop is mainly due to impact.
3. **Fan type nozzle:** It is a nozzle which forms narrow elliptical spray pattern. In this type the liquid is forced to come out as a flat fan shaped sheet which is then broken into droplets. This nozzles is mostly used for low pressure spraying.

METHODS OF TOXICITY TESTING: BIOASSAY

Bioassay: Bioassay is made up of two words namely `bios' meaning life and 'Assay' means determination. It is the determination of response of a chemical on living organism.

According to Finney (1952) bioassay means the measurement of the potency of any stimulus which, may be chemical, physical or biological, by means of the reactions which it produces in a living organism.

Importance of bioassay:

- Bioassay helps in ascertaining the potency of the insecticide.
- Relative toxicity of different insecticides can ascertain.
- Insect resistance to different insecticides can be studied.
- Micro quantities of insecticidal residues retained by the plants can be deduced.
- Formation of toxic metabolites produced from the insecticides can be assured.
- New formulations can be developed.
- Helps out to find the property of synergisms or antagonism of a compound.

Different methods of bioassay are

- Direct
- exposure method
- Aqueous solution method
- Film or residue deposit method
- Topical application method
- Injection method
- Sandwich method
- Dipping method
- Leaf dipping method
- Fumigation method

1. **Direct exposure method:** The insects are exposed to materials without extraction. The toxicant may be picked up by insects by feeding, by contact or vapour. The mortality counts are made after specific period of time
2. **Aqueous solution method:** In this method measured quantity of insecticide mixed with water in a suitable container. Known numbers of insects are released into the container for a definite period and number of insects alive or dead are counted. This method is normally used for aquatic insects like mosquito larvae.
3. **Film or residue deposit method:** The insecticidal solution is deposited o glass surface or Petri dish. The test insects are then exposed to the film of the toxicant in the Petri dish. The insects pick up the toxicant through its tarsi and gets killed. The mortality is counted after a definite period.
4. **Topical application method:** In this method small amount of toxicant is applied topically on the body of insects by means of topical applicator. Uniform spray or dusting on the insect body can be done by means of Potter's tower or dusting tower. Mortality counts are taken after a specific time period.
5. **Injection method:** The toxicant is directly injected in the body system of organism by hypodermic needle. The quantity of toxicant is measured precisely by micrometre.

6. **Sandwich method:** In this method measured amount of insecticide is put in between two leaves and the test insect is allowed to feed on it. It is generally used f leaf eating caterpillars.
7. **Dipping method:** Maggots of some dipterans are dipped in the solution for few seconds or minutes depending upon the standardization
8. **Leaf dipping method:** The leaves are dipped in aqueous solution of insecticide for a definite period, then they are taken out. After few minutes the known number of insects are allowed to feed on these leaves and the mortality counts are de after a definite period.

DETERMINATION OF LC50: PROBIT ANALYSIS

Probit analysis: The most common way of estimation of LC, is from the regression line relating the log dose to a transformed percentage response. There are many transformations of proportions, viz., angular, logit and probit transformations. Of these, a probit transformation is very commonly used.

Probit is the short form of probability + unit. Prepare different concentrations of test insecticide and release a known number of insects of same age in each concentration. After fixed duration note down the mortality of insects in the treatment as well as in control. Find out the log value of the concentration of insecticides used, with the help of log table and denoted as x. Write down the value of actual concentration used in the column I and of x in column two of the table 1.

Write down the number of insects released denoted as 'n' for bioassay at a particular concentration in column 3 of the table. With the help of the data on mortality of test insects calculate the percentage of mortality and write in column The corrected mortality can be calculated by using Abbotts formula:

$$T= C/100-C \times 100$$

Where, T= % mortality in the treatment C=% mortality in the control

Write down the corrected mortality in column 6 of the table. Obtain the empirical probit value with the help of the data of corrected mortality from the Finney's book of Probit analysis. These values are written in column 6 of the table.

Plot empirical probit against the log doses (x) on graph paper. Draw a provisional straight line to fit the points, judging the position by eye. While fitting such straight line it should be taken into account that the line passed closely through the points corresponding to the probits of 20 to 80% mortality. Now substitute the actual points plotted on the graph on the straight eye fit line. The shifted points corresponding to log doses (x) would be expected probits (Y) which should be written in column 7 of the table. Using the value of expected probit corresponding with natural percentage of mortality find out weighing coefficients with the help of the Table 2 of the Finney's book.

These weighing coefficients are denoted by w' and written in column 8 of the table. With the help of data on expected probit and corrected percentage of mortality find out the value of working probit (Table 4 of the Finney's book). It is denote by 'y' and written in column 9 of the table.

In other columns (10 to 15) of the table the results of the multiplication of day written in columns of the table are to be put in and sum of the data for each dose response filled in these columns be made so as to obtain Σ nw, Σ nwx, Σ nuy Σ nwxy, Σ nwx^2 and Σ nwy2

Calculate the values of and $\bar{y}$

$$= \Sigma nwx/ \Sigma nw$$

$$\bar{y} = \Sigma nwy / \Sigma nw$$

Calculate the value of regression coefficient by the help of following formula, Where $b = \Sigma xy/ \Sigma xx$

$$\Sigma xy \text{ Inwxy } (\Sigma nwx) (\Sigma nwy)/(\Sigma nw)$$

$$\Sigma xx \Sigma awx - (\Sigma nwx)/ \Sigma nw \Sigma\chi \text{ Apply regression equation } y = \bar{y} + b (x-)$$

Y = Probit of 50% mortality (From table 1 of Finney's' book)

$\bar{y}$ = means

b= regression coefficient x= log concentration

$\bar{A}$ = means

Take the antilog of the value x which would be the concentration of insecticide capable of killing 50 per cent population i.e. LC

The regression equation is also helpful to work out LC, and LC, or any other 30 lethal concentration/dose. First find out the empirical probit against the mortality for which lethal concentration is to be determined (from table 1 of Finney's book) and then such probit value be used in place of Y in the regression equation. The antilog of x so worked out from such equation would be the lethal concentration/dose against that particular mortality.

Table1

Concentration or dose	Log of concentration or dose 9x	Number of insects released (n)	Mortality (%)	Corrected mortality per cent (P)	Empirical probit	Expected probit (Y)
1	2	3	4	5	6	7

Table 2

Weighting coefficient (w)	Working probit (y)	nw	nwx	nwy	nwxy	Nwy^2	Nwx^2
8	9	10	11	12	13	14	15
		$\sum nw$	$\sum nwx$	$\sum nwy$	$\sum nwxy$	$\sum nwxy^2$	$\sum nwx^2$

INSECTICIDE'S CALCULATIONS OF VARIOUS FORMULATION:

For Emulsifiable Concentrate (EC) and Wettable Powder (WP) Formulations:

$C_1V_1 = C_2V_2$

Where,

C_1 = Concentration of given formulation (%)
V_1 = Volume / amount of formulation required (ml or g)
C_2 = Concentration of spray fluid required (%)
V_2 = Volume / amount of spray fluid required (ml or g)

For Granules and Dust Formulations

C_1V_1 = 100 RA
C_1 = Concentration of formulation available (%)
V_1 = Amount of formulation required (g or kg)
R = Recommended rate of pesticide application [g or kg active ingredient (*a.i.*)/ha]
A = Area to be treated (ha)

Calculation of Formulated Product Requirement

Quantity of formulated product required for spraying one hectare of land –
Commercial product (g/ ha) = Dose in g. *a.i.* per ha / Percent *a.i.* in Kg or L formulation x 100

PESTICIDE HAZARDS IN NATURE

Pesticide hazards: Hazard refers to the risk or danger of poisoning when a chemical is used or applied. Hazard depends not only on the toxicity but also on the chance of exposure to the toxic amounts of the pesticides. Pesticides cause hazards in 3 different ways:

1. During manufacturing and formulations
2. During application
3. During consumption of treated produce

The hazards are caused in two ways:

1. By drift of pesticides polluting the environment such as air, water and soil.
2. Toxic residues on the treated crops.

The various hazards caused by pesticides are:

- Hazards to man
- Resistance development in insects
- Pest resurgence
- Secondary pest outbreak
- Danger to pollinators
- Effects on wild life
- Deleterious effect on plant
- Hazards of pesticides residues
- Danger of fire
- Diseases
- Upsetting the ecological balance

Hazards to man: Insecticides are highly toxic to wide range of animals including man. Persistent insecticides contaminate the environment and reach human be through food, water, milk and meat.

Resistance development in insects: Insect develop resistance to insecticides and cannot be controlled.

Pest resurgence: Insecticides lead to pest resurgence in two ways. They induce resistance in insects so that after an initial decline they start growing in number again. Insecticides destroy parasites and predators leading to pest resurgence.

Secondary pest outbreak: The use of broad spectrum insecticides kills the major pest along with the natural enemies. The major pest is controlled, but minor per becomes major in due course of time. This is called secondary pest outbreak.

Danger to pollinators: Pollinators like honey bees are adversely affected by indiscriminate use of insecticides resulting in poor yields of fruits and seeds. The danger of pesticides to bees comes not only from direct contact poisoning bet also from the taking of poisoned nectar into hives.

Effects on wild life: Vertebrates and invertebrates are adversely affected by use of insecticides. Water contaminated with insecticides not only kills the aquatic insects which are food to fish but also accumulate in fish body by million fold. May birds particularly fish eating ones die of insecticidal poisoning.

Deleterious effect on plants: Some insecticides cause phyto-toxic effects of plants, destroy the germinating power of seeds and impart off flavour to the edible parts.

Hazards of pesticides residues: Residues of persistent insecticides accumulate in lakes and oceans and undergo biological magnification affecting fishes, birds and human beings at the terminal end of food chain.

Danger of fire: Inflammable fumigant insecticides cause accidental fires and dast explosions in buildings and godowns.

Diseases: Pesticidal pollution cause several diseases such as cancer, encephalitis, filariasis etc in human beings and domestic animals.

Upsetting the ecological balance: Insecticides tend to upset the balance of nature, by destroying wildlife, plants and insects.

INSECTICIDAL RESISTANCE MECHANISMS IN INSECTS

Insecticide resistance: The development of an ability in a strain of insects to tolerate doses of toxicant which would prove lethal to majority of the individuals in a normal population of the same species.

Types of resistance

1. **Simple resistance:** Resistance is limited to only one insecticide and not to the related ones.
2. **Cross resistance:** An insect resistant to one insecticide is also resistant to the related ones.
3. **Multiple resistance:** The co-existence of different defence mechanisms in the same strain.
4. **Monogenic resistance:** Single gene is involved in the development of resistance.
5. **Polygenic resistance:** Several genes are involved in the development of resistance.

The rate of development of resistance in a population depends on 4 factors

1. The frequency of resistant genes present in a population
2. The nature of genes (single or multiple; dominant or recessive)
3. The intensity of the selection pressure of the toxicant
4. The rate of breeding of the species

Mechanisms of resistance:

1. **Pre-adaptive (genetic) mechanism**
2. **Physiological mechanism**
   - Detoxification
   - Cuticular penetration
   - Increased storage
   - Decreased sensitivity of tissues
   - Dietary factors
   - Fat body insulation
3. **Behaviour and ecological mechanism**
   - Avoidance of treated surface
   - Decreased period of contact

MANAGEMENT OF INSECTICIDES RESISTANCE

Insecticide resistance management (IRM) -The strategies used to delay the onset of resistance to manage resistant populations are known as insecticide resistance management (IRM).

Steps to manage insecticide resistance:

- Judicious use of insecticides
- Insecticide rotation
- Use of undetoxifiable analogues
- Use of synergists
- Mixture and alternation of insecticides
- Negatively correlated insecticides
- Development of newer insecticides
- Use of insect pheromone and hormones
- Use of integrated approach

VARIOUS TOXICITY LABELS OF AGRO-CHEMICALS

Agro Chemicals are very important inputs in agriculture. Every year their requirement is increasing because for various reasons. Hence the utilization of agro chemicals is very important. How to Use, One has to know what dose to use, which agro chemical to use. Apart from that, one should also know the pesticide toxicity label or the agro chemical toxicity label and the toxicity labels of pesticides or Agro Chemicals.

Sl. No.	Label	Name	Level of toxicity
1.		Red Label	Extremely toxic
2.		Yellow Label	Highly Toxic
3.		Blue Label	Moderately Toxic
4.		Green Label	Slightly Toxic

BASIC PRECAUTIONS IN PESTICIDE USAGE

Precautions during purchasing time

- Purchase only JUST required quantity e.g. 100, 250, 500 or 1000 g/ml for single application in specified area.
- Do not purchase leaking containers, loose, unsealed or torn bags.
- Do not purchase pesticides without proper/approved LABELS.

Precautions during Storage

- Avoid storage of pesticides in the house premises.
- Keep only in original container with intact seal.
- Do not transfer pesticides to other container.
- Never keep them together with food or feed/fodder.
- Keep away from the reach of children and livestock.
- Do not expose to sun-light or rain water.
- Do not store weedicides along with other pesticides.

Precautions during Handling

- Never carry/transport pesticides along with food materials.
- Avoid carrying bulk - pesticides (dusts / granules) on head, shoulders or on the back.
- D. Precautions for Preparing Spray Solution
- Use clean water.
- Always protect your NOSE, EYES, MOUTH, EARS and HANDS.

- Use hand gloves, face mask and cover your head with cap.
- Use polyethylene bags as hand gloves, handkerchiefs or piece of clean cloth as mask and a cap or towel to cover the head (Do not use polyethylene bag contaminated with pesticides).
- Read the label on the container before preparing spray solution.
- Prepare spray solution as per requirement.
- Do not mix granules with water.
- Concentrated pesticides must not fall on hands etc. while opening sealed containers. Do not smell the sprayer tank.
- Avoid spilling of pesticide solution while filling the sprayer tank.
- Do not eat, drink, smoke or chew while preparing solution.
- The operator should protect his bare feet and hands with polyethylene bags.
- Select right kind of equipment.
- Do not use leaky, defective equipment.
- Select right kind of nozzle.
- Don't blow/clean clogged- nozzle with mouth. Use old tooth- brushes tied with the sprayer and clean with water.
- Do not use same sprayer for weedicide and insecticide.

Precautions for applying pesticides

- Apply only at recommended dose and dilution.
- Do not apply on hot sunny day or strong windy condition.
- Do not apply just before the rains and also after the rains.
- Do not apply against the wind direction.
- Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer.
- Wash the sprayer and bucket etc. with soap water after spraying.
- Containers, buckets etc. used for mixing pesticides should not be used for domestic purposes.
- Avoid entry of animals and workers in the fields immediately after the spraying.

Disposal

- Left over spray solution should not be drained in ponds or water lines etc. Throw it in barren isolated area, if possible.
- The used/empty containers should be crushed with a stone / stick and burned deep into soil away from water source.
- Never re-use empty pesticide container for any purpose.