ICAR

NAVSARI AGRICULTURAL UNIVERSITY

PRACTICAL MANUAL

Ag. Ento. 4.2 (1 + 1)

PRINCIPLES OF INTEGRATED PEST MANAGEMENT

Fourth Semester B.Sc. (Hons.) Agri.
Sponsered by ICAR

Prepared and compiled by:

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Navsari Agricultural University,
Waghai (Dangs) – 394730.


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FOREWORD

The science of Entomology which is an offshoot of Zoology or Life science is considered a difficult discipline by Graduate students as it contains many vocabularies of Latin and Greek origin. To make it simpler and understandable, there is an urgent need to have a practical literature pertaining to the discipline. As per ICARs Fifth Dean recommendation, many compulsory courses of Entomology are being offered in Graduate degree programme in the Faculty of Agriculture. One such course is **"Principles of Integrated Pest Management (Ag. Ento.4.2)"**. This course is considered as a link between Fundamental and behavioural science of Insect Ecology on one hand and Practical and Applied Entomology of Integrated Pest Management on the other hand. So, looking to the course curriculum and need, the practical manual has been prepared.

It gives me great pleasure to write the Foreword of the Practical Manual of this course which has been compiled and prepared by Prof. D.M. Damasia, Dr. J.J. Pastagia and Mr. H.R. Kachhela of this college. As a matter of fact being Entomologist, I have always been of the opinion that field and laboratory exercises done by students must be referred to a laboratory manual which could save their precious time otherwise they would end up referring to series of books many of which may not be related to the course. The efforts of the authors of this manual are laudable and need sincere appreciation. This is one of the most unique practical manuals available for fulfilling the requirements of the Undergraduate students. The manual consists of nine exercises based on the prescribed course curriculum of Fifth Deans Recommendation of ICAR. These are comprehensive and exhaustive in enriching the knowledge of integrated pest management.

I am sure that this publication would be of immense use to the students of Entomology.

(Z. P. Patel)

NAVSARI AGRICULTURAL UNIVERSITY

DEPARTMENT OF ENTOMOLOGY
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CERTIFICATE

This is to certify that Mr./Ms.____

Reg. No.________________ has performed practicals for Fourth semester B.Sc. (Hons.) Agriculture in the course No. **Ag. Ento. 4.2 Principles of Integrated Pest Management** Credits: 1+1 during the academic year ____________.

He/She has performed ________ practicals out of 9.

University Seat No. ____________

Course teacher **External examiner**

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EXERCISE – 1
SAMPLING TECHNIQUES FOR ESTIMATION OF INSECT POPULATION AND DAMAGE

Selection of an appropriate sampling technique depends initially on the kinds of estimate desired. Estimation can be divided into three broad categories *viz.,* absolute, relative and population indices.

I. Absolute estimation:

Absolute estimate measures actual number of the insect population. Such estimates are expressed in numbers per ground surface area *i.e.* numbers per acre or hectare or square meter. Absolute estimates are of extreme important in population dynamics of insect pests but due to the cost, generally they are not used widely in pest management practices.

Methods of absolute estimation:

(1) Quadrate method: Small area or quadrates are chosen at random from large area. From the quadrate, the insects may be counted or collected directly in case of fairly immobile but relatively large insects such as cutworms, caterpillars and grass hoppers. In case of borer's *viz.,* sugarcane borer, maize borer etc, the estimation is carried out by first removing the infested plants from the quadrates and then counting after splitting plant parts.

(2) Line-transect method: The number of individuals can be counted while walking in a straight line at a constant speed through the habitat. This technique is used for quantitative comparisons both between different occupiers of habitats.

(3) Capture, marking release and recapture method: This technique is generally used for estimating the population of flying insects/ animals e.g. butterfly, moths, dragonfly, birds etc.

II. Relative estimation:

In relative population estimates, the samples usually represent an unknown constant proportion of the population. Such estimates are useful in making comparisons in space or time. A given amount of labour and equipments are utilized to yield much more data.

Methods of relative estimation:

(1) Catches per unit time or effort: Various types of hand collection nets are used in different habitats. The sweep net is used widely for sampling insects from vegetation/ orchards e.g. mango hopper.

(2) Use of traps: Traps are of two types' *viz*., interception trap and attractant traps. The interception traps provide index of absolute population more easily than those of attraction trap. Various types of interception traps are flight traps, aquatic traps, pitfall trap, light trap and other visual traps. The traps that attract the insect by some natural stimulus or substitute include shelter trap, trap crops, bait traps, chemical attractants and pheromones.

III. Population indices:

Population indices do not count insect at all but rather they are measures of insect products or effects.

Methods of population indices:

(1) **Insect products:** The insect product most often sampled is frass or excrement of lepidopterous defoliators.

(2) **Plant damage:** The amount of damage caused by insects to crop plants is a function of the pest density. The characteristics of feeding or ovipositional behaviour and biological characteristics of the plants are used.

(3) **Direct pests:** The pests attacking on plants directly and destroying a significant part of its value e.g. bollworm in cotton and fruit borers in fruit and vegetable crops.

Sampling techniques for major insect pests:

Crop	Pest	Economic threshold	Method of sampling
Cotton	Leaf hopper (Jassid)	5 nymphs /leaf or yellowing and curling of 20% leaves from margins	Count leafhopper nymphs from underside of three fully developed leaves in the upper canopy of each of 20 random plants or count leaves showing yellowing and curling from margins and healthy leaves of 20 random plants in a field.
	Whitefly	5-10 adults/leaf	Count whitefly adults as above.
	Spotted bollworm	5-10% drooping shoots or 5-10% infested fruiting bodies	Count drooping shoots and healthy shoots of 20 random plants or examine all green fruiting bodies of the above plants for spotted bollworm induced holes or damage.
	Pink bollworm	5-10% infested fruiting bodies	Count rosette flowers and examine all fruiting bodies for damage by pink boll worm on 20 random plants
	American boll worm	5-10% infested fruiting bodies or one larva/ 2 plants	Examine all fruiting bodies of 20 random plants for the pest damage and also count number of larvae present.
	Aphid	5-10 aphid/ leaf or 10-15% infested plants	Examine presence of aphid or its symptoms on 20 random plants
	Thrips	5-10 thrips/leaf or 25% infested plants	Same as for aphid

Paddy	At ear-head stage; leafhoppers	5-10 insects/ hill	Select 20 hills randomly and shake vigorously and count leafhopper fallen on water.
	At flowering stage: Stem borer	5-10% plants with dead hearts or 2% white ears or one egg mass or moth/m^2.	Same as above Count infested and healthy tillers in 20 random plants.
	Leaf-folder	2 damaged leaves/ plant or one larva/hill	Count infested and healthy plants among 20 random plants or count number of larvae in 20 plants.
	Root weevil	2 grubs/hill	Same as above
	Rice *gundhi* bug	1-2 insects/hill	Count the insect on 20 random plants.
Sugarcane	Early shoot borer	Dead hearts in 5-10% tillers	Examine 100 tillers/ row for dead hearts from the 5 randomly selected rows.
	Top borer	Dead hearts in 10% tillers or 5% dead hearts in the ratoon crop	Same as for early shoot borer
	Pyrilla	3-5 insects/leaf	Count pyrilla nymphs and adults on 10 random plants taking 6 (2 upper, 2 middle and 2 lower) leaves/plant
Sorghum	Shoot fly: After one week of crop germination. After two weeks of germination.	One egg/ plant or presence of eggs on 5% plants. Dead-hearts in 5-10% plants	Examine 20 plants for the presence of eggs Examine 20 plants and count the number of dead hearts
	Stem borer	Symptoms of damage (i.e. dead hearts, shot holes in leaves, unfilled ear head etc.	Examine 20 plants for damage symptoms.
	Sorghum midge	One midge/ear head at 50% flowering plants	Count gall midge adults on 50 earhead random in the morning.
Gram	Gram pod borer	20 larvae per 20 plants at vegetative stage and 15 larvae per 15 plants at fruiting stage	Record from the 20 randomly selected plants

Okra	Leafhopper	5-10 nymphs/leaf	Same as in the case of cotton.
Tomato	Fruit borer	One larva/ plant	Count number of larvae from the 20 randomly selected plants.

Answer the following questions:

1. Draw a diagram of the following traps

(a) Fennel trap

(b) Yellow sticky trap

(c) Pit fall trap

(d) Light trap

EXERCISE – 2
CROP LOSSES CAUSED BY PESTS AND THEIR ASSESSMENT

Before studying the losses caused by insect pests to crops and methods to assess them, it is important to understand the terms pertaining to the topic. Some of the terms are discussed as under.

Yield: Yield is a measurable produce of economic importance from a crop. The yield may be evaluated in terms of quantity and/or quality. The distinction between total yield and marketable yield is important if marketability and /or value of the crop is determined by its quality i.e. commercial class or grade.

Production: It is the total amount harvested in a country or in a region in a year.

Theoretical yield: It is the yield obtained from a crop grown under most favourable conditions. There is no factor limiting the yield potential of the crop, only genetic factor are limiting.

Attainable yield: It is the site specific maximum yield that can be obtained under the geographic and ecological conditions at a location using best production techniques to avoid biotic stress. It is determined by factors like climate, latitude, and variety grown.

Actual yield: It is the site specific yield obtained when the crop is grown using available cultivation and plant protection practices at a particular place.

Crop loss: A crop loss is any reduction in quantity and/or quality of yield and is the equivalent of 'damage' Crop loss is measured as the difference between actual yield and attainable yield due to the effect of one or more pests. The term yield loss should be restricted to describe the reduction in yield caused by a single pest.

Direct losses: These relate to the decrease in productivity (quantitative) or intrinsic value/acceptability of the produce (qualitative). Direct losses include killing of flowers, buds, fruits, twigs or whole plant due to the attack of insect-pests. The examples of indirect qualitative losses include light infestation of fruits by scales, puncturing of fruits.

Indirect losses: These are primarily of economic interest i.e. decreased purchasing power of farmers due to reduced production. These will lead to decrease in related activities, reduced productivity of agro based industries and forced acceptance of less desirable substitute products.

Actual losses: These include the sum total of both direct as well as indirect losses. Potential losses: These refer to the losses likely to be sustained without the adoption of the plant protection measures.

Avoidable losses: It is that proportion of the losses that can be saved by adopting proper crop protection measures.

Unavoidable losses: It is that proportion of the crop losses that cannot be prevented by using the available crop protection technology.

Efficiency of crop protection: It is defined as the percentage of avoidable losses which are actually prevented by the use of crop protection measures.

Efficiency of crop protection = 100 (Actual yield – yield without crop protection)/(Attainable yield - yield without crop protection)

Methods of estimating the crop losses:

Estimation of crop losses caused by the pests is very important in pest management programmes.

Estimation of pest damage is use full in pest management in following ways:

- To determine the economic status of a given pest species.
- For establishing the economic threshold levels and economic injury levels of the pest.
- To estimate the effectiveness of control measures.
- For evaluating the crop or a variety for its reaction to the pests.
- Helping in deciding the allocations for research and extension in plant protection.
- Helping in assigning the priorities on the bases of relative importance of different pests.

A brief account of the techniques adopted for the assessment of crop losses caused by insect-pests has been given below:

Mechanical protection: The crop is grown in enclosures under protected conditions by using antiinsect nets or cotton cloths in order to keep the pests away. The yield obtained under theses enclosures is compared with that obtained from infested crop grown under similar conditions. This technique has been used with various modifications for estimating the crop losses caused by jassids and whiteflies. The limitation with this method is that the plants generally become week and pale in enclosures due to changes in micro-environment. Further, this technique cannot be used on a large scale because it is time consuming and impracticable under field conditions.

Chemical protection: In this case the crop is protected from pest damage by applying chemical pesticides. The yield of treated plot is compared with that of untreated which is exposed to natural infestation. This technique has been extensively used and can be employed on a larger area. Here care should be taken that the treated and untreated plots should be as identical as possible in respect of soil type, variety grown, fertilization and other cultural practices. The major drawback in this method is that the crop treated with chemicals may be physiologically affected and hence may vary in yield to some extent.

Comparison of yield in different fields: In this case the yield of the crop is calculated per unit area in different fields having different degree of infestation. Correlation between crop yield and level of infestation is worked out to estimate the loss in yield. This technique can be used for estimating crop loss due to different pests over a larger area, however the soil heterogeneity may influence the yield.

Comparison of yield of individual plants: In this case the yield of individual plants in the same field is measured and the average yield of healthy plants is compared with the plants showing different degree of infestation and the loss in yield is estimated. The data so obtained can also be used to work out the correlation between yield and infestation level on the bases of the yield of individual plants. This technique has been used with different modifications for the estimation of crop losses in different crops. In this case the soil heterogeneity is greatly reduced, however, plant to plant variation in infestation level may be there.

Damage caused by individual insect: Preliminary information is obtained from studies on the biology of the pest. The details regarding the amount of damage caused by different stages of pest are worked out and the amount of loss is calculated. This technique is quite convenient in case of leaf feeding insects. However, it is difficult to use this technique over a large area because it is time consuming.

Manipulation of natural enemies: Here the pest is controlled by introducing the natural enemies in to the field and the yield is compared with the plot without natural enemies. This technique is also feasible in a small area.

Simulation of damage: In this method the pest injury is simulated by removing or injuring the plant parts. The simulated damage may, however, not always be equivalent to the damage caused by an insect. Insects may inject toxins in to the plant rather than producing injury instantly. Feeding on margins of the leaf may not be equivalent to the tissue removed from the centre of the leaf. Insect feeding is usually extended over a period of time and is rather difficult to incorporate the concept of rate of injury in simulating studies. Furthermore the period of leaf removed may be important, as for example the age, quality and position of the leaf on the plant. In addition the time of simulating damage with respect to the stage of growth is also critical. Simulated studies have been done on spotted boll worm in cotton in India.

EXERCISE – 3
PEST SURVEILLANCE THROUGH FIELD INCIDENCE, LIGHT TRAPS AND PHEROMONE TRAPS

Monitoring of insect pests activity through regular surveys is an important component in Integrated Pest Management (IPM). Different activities of insect such as their population on crop, damage inflicted to the plants, insect stage(s) present, local movement, migration and dispersal etc. can be documented through surveillance.

The surveillance refers the close vigil of the pest in the crop over a time. It will be useful for short term forecasting. A constant watch on population dynamics of pest, its incidence and damage on crop at fixed intervals to forewarn the farmers for taking up timely crop protection measures is essential.

Sampling insect population:

It is not possible or even desirable to count all the insects in a habitat. Therefore, to estimate the population density of a pest or the damage caused by it to the crop, one has to adopt the samplings. Randomization and choice of sample unit are the fundamentals of sampling. The total number of samples to be taken depends on a degree of precision required.

Common Sampling Techniques and their application:

Sampling techniques is the way how insects are counted, weather with necked eye or taking help of some equipment. There is no single sampling technique which can work for all categories of pests. The selection of sampling techniques also depends on the pest's biology and ecology. Some of the most commonly used techniques and their applications are as under:

In situ count:

It involves direct counts or direct observations and often requires no special equipments but relay on good eye. For example making count of leaf hopper nymph on cotton leaves or recording of egg or larval population of *Helicoverpa armigera* etc. This technique is useful for counting large and conspicuous insects usually on a part of a plant (e.g. leaves) or whole plant (if plant is small). However for smaller insects like aphids and thrips or for mite, help of hand lens may be required for counting. Further, when these insects are in a large number, 1 cm^2 windows may be cut out in a thick paper sheet and place on a leaf surface for counting the insects visible through window.

Knockdown:

Knockdown is similar to *in situ* counting except that the insects are dislodged from the plants causing them to fall into either a tray, a funnel or on a sheet or on a piece of cloth and are subsequently counted. The methods for dislodgement may be jarring, chemicals or heating.

Jarring: It is probably the most common method of knocking down insects from the plants and particularly useful in collecting the white grub beetles *(Holotrichia* spp*.)* from the trees soon after emergence from the soil during night after first heavy monsoon rain. A piece of cloth is placed on the ground and a branch is given jerks several times with the help of an iron hook attached to a stick to dislodge the beetles. Beetles falling on the cloth are counted. Similarly, gram pod borer *(H. armigera)* larvae may be sampled by shaking chickpea plants vigorously over a piece of cloth or a chart-sheet and the larvae falling on the sheet may be counted. This is also known as drop sheet method. However, jarring may not be effective for species concealed within vegetation e.g. galls, leaf-miners, etc.

Beat-bucket method is also used in which top *25* cm portion of cotton plant is to be bent in a plastic bucket and beaten against the sides of the bucket to dislodge pests as well as arthropod predators.

Chemicals: In certain cases, the whole plant or several plants may be enclosed in a polyethylene envelope and treat with a quick-knockdown insecticide such as pyrethrum or dichlorvos. After some time, the plants may be shaken to remove dead or immobilized insects on a cloth or other container for counting.

Heating: Heating envisages forcing the insects to come out of their dwellings by increasing the temperature of their habitat. Here, the plant sample harbouring insects may be placed in a special device, the Berlese funnel that heats the sample. Finding the plant habitat inhospitable, insects move out of the plant material, fall through a funnel and are retrieved from a container for counting. This approach saves time and efforts but sometimes insects may die during the extraction process. Thus, insects may not come out and may not be counted.

The other techniques of dislodging insects from their substrates include washing insects from plants or plant parts with soap, alcohol or other solutions. A special brushing machine may be used to remove mites from the leaves.

Netting

Netting of insects is one of the most widely used techniques which relatively simple and inexpensive. It is particularly useful in the case of small insects and those with poor clinging habit. However, the major disadvantage of this technique is that there is great sampling variability. This technique is closely related to jarring when used to sample insects in a plant canopy. Netting may be of several types:

Sweep netting: Muslin net is swept through the crop canopy (generally 20 cm deep) and on jarring; insects present on the plant may fall down into the net. After 20-25 swings or sweeps, remove the plant debris and count the insects. Efficiency of sweep net varies with species, crop height, wind speed, time of the day and the person doing sweeping. The sweep catch is expressed as the mean number of insects per sweep. The limitation with sweep netting may be that if there are changes in vertical distribution of the pest within the vegetation, the pest may not be detected. Further, various crops may require different sweeping technique which need to be standardized.

Vacuum netting: Engine power is used to create strong vacuum which sucks the insects from plant canopy. Such nets have been used for sampling insects like leafhoppers.

Aerial netting: Aerial nets are used for sampling air-borne insects. A true aerial net is a mesh-bag net with a handle which is swept through the air to capture the insects. Other aerial nets include rotary net and tow net. The rotary net consists of one or two nets at the ends of beams that are rotated by a motor-driven shaft. The insects collected are counted after a given period of time. Tow nets are attached to the moving aircraft, automobiles or ships to detect insects.

Pheromone traps:

The first step to IPM is the timely detection of pest infestation. Insect traps not only allow detection and monitoring of pest but also provides estimates regarding pest population density in the sample area. If conducted consistently over multiple years, insect traps can indicate critical changes in population dynamics and behaviuor of key pests. In commercial agriculture, pheromone traps are commonly used for monitoring the insect pests by luring into the trap either by using pheromones (= scents), shape and/or colour. It can be provided the information's for calculating economic threshold level (ETL). Long-term monitoring with multiple traps can save thousands of rupees of insecticides and protect the environment.

Pheromones are substances in a small amount attract the insects toward the emitter. Pheromones are natural substances those are produced by special glands of insects and it attracts the opposite gender of the same species. Insects produce pheromones for attracting the mate (e.g., most moths), for marking foraging routes (e.g., ants) or to signal alarm to neighbours (e.g., aphids). In case of pheromone traps, the lure slowly releases synthetic attractants that helps in detection of a single species of insect. Pheromone trap is an effective monitoring device and is relatively cheap to purchase. Product assemble is very easy. Store the unopened lures in cool and dark place and can be used for a long time.

Basic parts of winged pheromone trap:

1) Top section
2) Bottom section
3) Lure

Monitoring Insect Pest Population Using Traps:

One of the major advantages of using insect pheromone traps with lure is that they are designed to attract single species of insect. Some other flying insects may accidentally visit the trap but their numbers will be lower than the target pest. Therefore, insect identification is automatic with lure-based traps. Individual traps should be separated by at least 15-20 m apart or follow specific product directions. In some cases, pheromone traps data can be used in decision support system in IPM e.g. *S. litura, H. armigera, E. vittella, P. gossypiella, P. xylostella* etc.

Light trap:

It is the most widely used visual trap employed for sampling and monitoring of moths, hoppers and beetles. A light trap consists of a light source above a funnel and a container below to collect the catch. It is covered with a protective roof. The light source is generally an oil lamp or electric bulb or UV tube or a fluorescent tube. Insecticides with quick knockdown or fumigant action such as dichlorvos are sometimes added in the container for killing the trapped insects. Many moths (particularly noctuidae) are attracted to short wavelengths of the light spectrum or the back light. Black light lamps emitting ultraviolet light are widely used in different trap designs. Light traps have been used for many years to monitor long term population changes in nocturnal flying insects, particularly moths. They also provide information on their time of arrival in a particular locality e.g. *Spodoptera.* Large number of non-target species which may include useful ones also, get trapped, which not only makes sorting cumbersome but also disturbs ecological balance, this is the major limitation of light trap.

Operating principle:

When insects get in to the region of high luminous flux, their eyes rapidly become light adopted. UV and visible radiation cause migration of the ommatidial protective pigments from nocturnal to diurnal position and visual sensitivity decrease by hundreds and thousand times and insect cannot distinguish object at lower level of illumination. The lamp is the only thing. the insects are now able to see and they cannot fly to the sides of it in darkness of the night. Thus, insects' attraction to light and their trapping is purely a function of contrast effect in illumination.

Answer the following questions:

1. Enlist the insect pests those can be trapped by pheromone traps?

2. How many pheromone traps are required in brinjal, chickpea and okra for the control of *L. orbonalis, H. armigera* and *E. vittella* for mass trapping?

3. At what height and distance, the pheromone traps should be kept in brinjal, okra and chickpea?

4. What are the limitations of pheromone traps?

5. Which are the different types of light traps?

6. Enlist the sources of light that can be utilized in the light trap and which one is more effectively attract the insect pests?

7. How UV or Pesto-O-Flash light traps are working?

8. What are the limitations of light traps?

9. How light traps are useful in IPM?

10. Collect the observations on the light traps installed in our fields.

Week and date	UV light trap				Florescent light trap				Common light trap			
	Lep.	Col.	Hym.	Others	Lep.	Col.	Hym.	others	Lep.	Col.	Hym.	others
1.												
2.												
3.												
4.												
5.												
6.												
7.												
8.												
9.												
10.												
Av.												

Lep.: Lepidopteran, **Col.:** Coleopteran, **Hym.:** Hymenopteran

Conclusion:

EXERCISE – 4
PEST MONITORING TECHNIQUES

Once a pest manager has taken precautions to prevent pest infestations, it is important to watch regularly for the appearance of insects, weeds, diseases, and other pests. This is called monitoring.

The primary goals are to locate, identify, and rank the severity of pest infestations. These data may also be used to project future populations through pest management models. In addition to giving solid data for making a management decision, regular monitoring works well for checking the success or failure of a control strategy. Pest populations vary from field to field, building to building, and year to year. Managing pests requires flexibility and an absolute commitment to pest monitoring. Pest monitoring is site-, crop-, and pest-specific. Each situation will require specialized knowledge and tools.

Monitoring pests involves:

Regular checking of a crop field, garden, greenhouse, golf course, warehouse, bakery, restaurant, field, greenhouse, golf course, or other areas and **early detection of pests** function together like an early warning system for pests, helping to prevent or minimize a pest outbreak.

Proper identification of pests is an extremely important prerequisite to handling problems effectively. For example, the brown banded and German cockroach can be easily confused with each other. Identification is important because certain management practices may control only one species and not the other. Correct identification enables you to manage the real source of the problem and avoid merely treating the symptoms (or controlling organisms that are not pests). Some pests cause similar damage. Unless the pest is identified, the control program may have the wrong pest as its target. Identification enables you to cure the pest problem and avoid injury to non-target organisms, particularly if you use a pesticide that is specific to the pest control the pest effectively during the most susceptible stage of its life cycle consider the use of a non-chemical control.

Identifying the effects of naturally-present biological control agents means knowing which organisms are beneficial and determining if pests have been affected by them. Sometimes pests are kept in check naturally, and at other times the pest populations increase sharply.

Assessing the efficacy of pest management actions that have been taken is a very important part of monitoring. The scout must know the "what," and "where" of the management actions taken and report successes or failures.

Monitoring tools and techniques:

The IPM Scout or technician is the most important part of a professional monitoring program. The scout works in a variety of situations, each requiring specific knowledge and tools. However, diligent growers, golf course superintendents, homeowners, etc. can also monitor successfully for pests:

Tools

- Flashlight
- Black light (detect rodent urine)
- Video camera
- Screwdriver
- Putty knife
- Spatula
- Tracking patches or powders]
- Double-sided transparent tape (tree and shrub insects)
- Shovel or spade

Monitoring pest populations with traps. The use of monitoring traps is highly recommended for certain insects, rodents and diseases. Practically speaking, these devices are a must. They extend the eyes of the pest manager to places they cannot see and provide ongoing coverage.

Insect Monitoring Traps

Plastic bucket traps appear to be very efficient and economical.

Light traps are attractive to some insects, but pheromone traps offer increased flexibility in deployment and are much less expensive.

Sticky Traps: Some insects are attracted to bright yellow or other colors so they can be caught on colored sheets of plastic or cardboard that has been coated with glue. Sticky traps are usually used as a monitoring tool in greenhouses and orchards, although they can also be used as a control on indoor plants. By regularly checking the sticky traps a grower can find out when the first of the adult insects are present among the plants.

Yellow sticky traps attract adult whiteflies, flower thrips, fungus gnats, leafminers and cabbage loopers.

Bright blue traps are also available for flower thrips.

Pheromone Traps: Individually packaged pheromone attractant traps are available for monitoring some species of moths. The traps are baited with a lure that mimics the odor given off by female moths to attract males for mating. The traps are used to find out when the main flights of adult moths occur so that sprays can be put on at the right time to have the greatest effect. Orchard growers use traps to time codling moth sprays so that they are used when the most moth eggs are hatching into caterpillars.

Plastic pitfall traps are used for crawling pests in the field as well as in stored grain bins. The species and number of insects found in a trap should be recorded and charts constructed so that changes in population size can be easily noticed.

Vertebrate Monitoring Traps Small secretive and sometimes nocturnal vertebrate pests are difficult to monitor. Traps are very important when checking on domestic rodent populations, mice and rats.

- Snap trap (single catch),
- Automatic trap (multiple catch),
- Sticky trap (glue boards),
- Single catch live box traps.

Digital monitoring tools:

Computers and other electronic tools are very much a part of IPM monitoring. Geographic Information Systems and Global Positioning Systems allow very precise mapping of areas. These devices, when used with soil mapping and yield monitors are part of a system called “Precision Agriculture”.

Precision agriculture has a lot to offer IPM, by identifying many crop yield- or quality-reducing factors using technology such as remote sensing and geo-referenced crop scouting (to measure crop vigor, quality and disease), yield monitors (to show yield variation), and crop and pest modeling. Precision applications of products to control pests are often more effective than conventional methods, and require less pesticide. Yield monitors and site-specific crop quality data provide a report card on how effective the crop production products and management tactics were. For example, a predicted disease level can then be used as the basis for a variable rate fungicide application and provide decision support for various production practices, such rootstock selection, fertilization, and irrigation.

Geographic Information Systems (GIS) are databases that store the relationship between data collected and their locations. Locations may be in real-earth coordinates Universal Transverse Mercator (UTM) coordinate system, longitude/latitude, or on a grid (i.e. X, Y coordinates). A GIS combines digital mapping, database functions, and spatial analysis.

Global Positioning Systems (GPS) is a U.S. space-based system that provides reliable positioning, navigation, and timing service worldwide.

An example of a practical IPM use of these devices is as follows.

The GPS system is used to map blacklight trap locations in agricultural areas used to monitor for crop pests. (The GPS units are accurate to within 10 feet.)

The trap counts are collected and entered into an Excel database which is linked to the GIS software.

The GIS software is used to create a map of the counts.

The maps are shared with growers in the community by sending a newsletter, fax, email or an internet web page.

Mapping the trap counts is useful for predicting where and when a pest will be arriving. Additionally, the pest maps can be overlaid with weather maps that will help predict pest movement and the likelihood of damage to crops.

EXERCISE – 5
STUDY OF DISTRIBUTION PATTERN OF INSECTS IN CROP ECOSYSTEM

To study of distribution patterns of insects in a crop-ecosystem is most imperative to confirm methods for population assessment and to know the pest population. The information on distribution or dispersion of pest species provides a valid base for developing a sound sampling plan and gives information about behaviour of the insect species. The dispersion of species is influenced by social instinct such as breeding, protection against natural enemies and heterogeneity of the environment. Individuals of a population arrange themselves in a manner that is specific to each population and these arrangements in space appear to be of considerable importance in the study of dynamics of ecosystem.

A group of organisms of the same species occupying a particular area at a specific time is called population. The existence and abundance of the population in the area are determined by the physical and biotic influences of the environments as well as genetic makeup of the species.

Dispersal:

The movement of individuals in to or out of the population is called population dispersal. This plays an important role in the geographical distribution of insects to areas that were not previously occupied by them. Population dispersal may take place in search of food, to avoid predators, preventing overcrowding due to wind, water, light or temperature condition. The dispersal of population may occur in 3 ways.

Immigration:

One way inwards movement of individuals from one place to another is known as immigration. Insect pests generally arrived from somewhere else's *i.e.* from the countries without the deliberate helps of man.

Emigration

One way outwards movement of individuals from one place to another is termed as emigration.

Migration:

Mass movement of entire population where some insects return again to the area from which they have moved is known as migration.

Dispersion: Distribution or physical location of individuals within a population at a particular time called dispersion. The internal distribution patterns are important which are related with some characteristics of a population may be distributed according to three basic patterns.

I. Random/ poisson distribution

II. Uniform/ Regular distribution

III. Clumped/ aggregated/ over-dispersed/ contagious distribution

* ** * ** * ** ** * * * * * * ** * *	********************* ********************* *********************	*** ** ***** *** ** ***** ** *** ****
RANDOM	**UNIFORM**	**CLUMPED**

Record work: Work out mean, variance and different indices to conclude the pattern of distribution for *Spodoptera litura* infesting castor/ cabbage based on population of larva(e):

Name of crop: Cabbage and **variety**: Sutton express

Name of insect: Tobacco leaf eating caterpillar, *Spodoptera litura* Fabricius.

Name location:

Any plant protection measures taken before observations: No any insecticidal spray was given so far.

Condition of crop: Good

Name of the other insect pests which also observed simultaneously: Diamond back moth and aphids

Population of insects in field

Number of insects/ plant (x_i)	Plant frequency (f_1)	f_ix_i	$f_i\, x_{i*}\, x_i$
0	22	0	0
1	3	3	3
2	5	10	20
3	8	24	72
4	12	48	192
5	11	55	275
6	9	54	324
7	23	161	1127
8	7	56	448
9	6	54	486
10	4	40	400
	N = 110	Óf_ix_i= 505	Ó$f_ix_i^2$= 3347

(a) Mean ($\overline{X}$) = Óf_ix_i/n = 505 ÷ 110

= **4.5909**

(b) Variance (S^2) = $\dfrac{\text{Ó}f_ix_i^2 - (\text{Ó}f_ix_i)^2/n}{n-1}$ = $\dfrac{3347 - [(505)^2 \div 110]}{110-1}$

Where,

f= Frequency of number of plants/branches

x= Number of insects per plant/branch

n= Total number of plants

= $\dfrac{3347 - 2318.409}{109}$

= **9.4366**

(c) Variance Mean ratio (VMR) = $S^2/\overline{X}$ = 9.4366 ÷ 4.5909

= **2.0555**

(d) Index of David and Moore (IDM) = $[S^2/\overline{X}] - 1$ = 2.0555 – 1

= **1.0555**

(e) Index of Lexix (IL) = $\sqrt{S^2/\overline{X}}$ = $\sqrt{9.4366 \div 4.5909}$

= $\sqrt{2.0555}$

= **1.4337**

(f) Charlier Coefficient = $\dfrac{\sqrt{S^2 - \overline{X}}}{\overline{X}}$ = $\dfrac{\sqrt{9.4366 - 4.5909}}{4.5909}$

= **0.4795**

Conclusion: Here, variance-mean ratio (VMR: 2.055) is more than one; $S^2 > X$ (9.436 is more than 4.59); IDM is more than zero (1.055) and IL is more than one (1.433) and the Charlier Coefficient is more than zero (0.479). Hence, the insect distribution is aggregated/ aggregate/ negative binomial.

1) Regular / uniform distribution:

It may occur where competition between the insects is severe due to physical factors. Here, the variance is less than Mean ($S^2 < X$). Hence, the variance-mean ratio (VMR) is less than one, IDM is less than zero, Index of Lexis is more than one and the Charlier Coefficient is less than zero.

2) Random distribution:

It is relatively rare in nature and occurs where the environment is very uniform and there is no tendency to aggregate. Each insect has equal probability of occupying any point in space and the presence of one individual does not influence the distribution of another. Here the variance-mean ratio (VMR) is always one ($S^2 = X$), IDM is equal to zero, Index of Lexis is unity and the Charlier Coefficient is zero.

3) Aggregated/Clumped / Aggregate/Negative binomial distribution:

This is the most frequently observed pattern and individuals show varying degree of clumping together due to attraction or instinct as in case of some insects. Large scale clumping helps to evade possible danger of predation, climate or diseases. Bees are able to exist in cold climate by increasing the input of heat among them thus modifying the environments. Usually the environment decides the degree of aggregation of clumped patterns. Here the variance-mean ratio (VMR) is more than one ($S^2 > X$), IDM is more than zero, Index of Lexis is more than one and the Charlier Coefficient is more than zero.

Example 1: Record the population of any insect pests in the standing crop and work out mean, variance and different indices to conclude the pattern of distribution for ____________ infesting __________ crop based on population of _______________:

Name of crop: _______________________ and **variety**: ______________________.

Name of insect:____.

Name of location: ______________________________.

Any plant protection measures taken before observations:

____.

Condition of crop: _______________

Name of the other insect pests which also observed simultaneously:

____

Population of insects in field

Number of insects/ plant (x_i)	**Plant frequency (f_1)**	**f_ix_i**	**$f_ix_i^2$**
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
		Óf_ix_i=	Ó$f_ix_i^2$=

(a) Mean ($\overline{X}$) = Óf_ix_i/n = _____ ÷ ____

= _______

(b) Variance (S^2) = $\frac{\text{Ó}f_ix_i^2 - (\text{Ó}f_ix_i)^2 / n}{n-1}$ = $\frac{(\_\_\_)^2 - \_\_\_\_\_\_\_ \div \_\_\_\_}{\_\_\_ - \_\_\_}$

Where,

f= Frequency of number of plants/branches

x= Number of insects per plant/branch

n= Total number of plants

= $\frac{\_\_\_\_\_\_\_ - \_\_\_\_\_\_\_\_}{\_\_\_}$

= _________

(c) Variance - Mean ratio (VMR) = $S^2/\ \overline{X}$ = ______ ÷ ______

= ______

(d) Index of David and Moore (IDM) = $S^2/\ \overline{X}$ - 1 = ______ – 1

= ________

(e)	Index of Lexix (IL)	=	$\sqrt{s^2}/\bar{X}$	= $\sqrt{\_\_\_\_\_\_\_}$ ÷ ______
				= ______ ÷ ______
				= ______ ***i.e.*** _____
(f)	Charlier Coefficient	=	$\frac{\sqrt{s^2 - \bar{X}}}{\bar{X}}$	= $\frac{\sqrt{\_\_\_\_\_ - \_\_\_\_\_}}{\_\_\_\_}$
				= _____

Conclusion:

Example 2: Record the population of any insect pests in the standing crop and work out mean, variance and different indices to conclude the pattern of distribution for ___________ infesting _________ crop based on population of ______________:

Name of crop: _____________________ and **variety**: ____________________.

Name of insect: ______________________________________.

Name of location: ___________________________.

Any plant protection measures taken before observations:
____.

Condition of crop: ______________

Name of the other insect pests which also observed simultaneously:

Population of insects in field

Number of insects/ plant (x_i)	**Plant frequency (f_1)**	**f_ix_i**	**$f_ix_i^2$**
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
		Óf_ix_i=	Ó$f_ix_i^2$=

(a)	Mean ($\bar{X}$)	=	$\Sigma f_i x_i / n$	=	_____ ÷ _____
				=	_______
(b)	Variance (S^2)	=	$\frac{\Sigma f_i x_i^2 - (\Sigma f_i x_i)^2 / n}{n-1}$	=	(____)^2 – _______ ÷ ____ / ____ - ____
	Where, f= Frequency of number of plants/branches x= Number of insects per plant/branch n= Total number of plants			=	_______ – _______ / ____
				=	_________
(c)	Variance - Mean ratio (VMR)	=	$S^2 / \bar{X}$	=	______ ÷ ______
				=	______
(d)	Index of David and Moore (IDM)	=	$S^2 / \bar{X} - 1$	=	______ – 1
				=	________
(e)	Index of Lexix (IL)	=	$\sqrt{S^2 / \bar{X}}$	=	$\sqrt{\_\_\_\_\_\_\_\_}$ ÷ ______
				=	______ ÷ ______
				=	______ ***i.e.*** _____
(f)	Charlier Coefficient	=	$\frac{\sqrt{S^2 - \bar{X}}}{\bar{X}}$	=	$\sqrt{\_\_\_\_\_ - \_\_\_\_\_}$ / ____
				=	_____

Conclusion:

EXERCISE – 6
PRACTICABLE IPM PRACTICES: PHYSICAL AND MECHANICAL METHODS

Mechanical and physical control measures involve the use of force or physical factors of the environment with or without an aid of special equipments. The physical control measures give immediate real results and are generally popular to convincing the farmers even though they are time consuming, laborious and are often applied when much damage has already been done. These control measures are generally ineffective on a large scale and cannot be applied commercially.

Mechanical Measures:

It means, working with hands and sometimes the aid of some simple equipment like bags, nets etc.

(1) **Hand picking:** This is the most ancient method employed by man and is still being used for picking up the large sized caterpillars. In the field, insects can be picked up by hands when easily assessable and large and conspicuous sized insects and when present in large numbers e.g. *Spodoptera litura*.

(2) **Hand nets and bag nets:** The collection of adults with hand nets when insects are migrating from one location to another e.g. sugarcane pyrilla, surface grass hopper.

(3) **Beating and hooking**: Pulling out or killing off the insects with the help of brooms or thorny bushes. The rhinoceros beetle can be picked out from holes of coconut with the help of bent hooks made of iron.

(4) **Shaking and jarring**: Shaking of small trees or shrubs, particularly early in the morning in the cold season when the insects are less mobile and collecting them in open tubes containing kerosenized water or simply burying them in pits e.g. locust and defoliating beetles.

(5) **Sieving and winnowing**: These are commonly employed against insect pests of stored grains. A good number of insects can be removed with these operations e.g. the grubs of *Tribolium castatum* and *Trogoderma granarium* infesting wheat.

(6) **Clipping**: Clipping off the top of the rice seedlings containing egg masses of yellow stem borer and grub of hispa would reduce carry over of infestation from seedbed to field.

(7) **Mechanical exclusion**: Mechanical exclusion consists of the use of devices by which insects are physically prevented reaching crops and agricultural produce *e.g.*

(a) The application of fluffy cotton band of 15 cm wide or a band of sticky material on basal portion of mango tree trunk to prevent the upward movement of mealybug.

(b) Installation of screen's windows, doors and ventilators of storage godown to keep away is quite helpful.

(c) Wrapping individual fruits of pomegranate with butter paper envelopes to save them from attack of anar butterfly and fruit sucking moth. Maize cobs can be protected from the attack of crows by wrapping the nearest leaf around the exposed portion of the cob.

(d) Trenching around the fields or erecting barriers (30 cm high) in order to save crops from the invading bands of locust or red hairy caterpillars or armyworm.

(e) Light reflection by aluminum foil or light reflected by plastic ribbon bands will protect the crop from bird's attack.

(f) Scaring birds by creating noise with explosives is quite effective; an automatic device is available in which an explosive materials are loaded which gives frequent loud sound.

(g) Growing of bajra/ sorghum around the crop, prevent the entry of thrips.

(8) Mechanical trap: Various types of traps have been devised for collecting and killing the different types of insects.

Light traps: It can be used to attract and kill some of insect pests. An electric bulb or a petromax lamp or UV or florescent light is placed in the centre of wide flat vessel containing kerosenized water in which the moths or the beetles get drowned. Trapping adults through light traps proved as effective in IPM for the management of lepidopteron and coleopteran pests.

(a) Air suction traps: These may be fixed in godowns to trap stored grain pests.

(b) Electric trap: These are live metal screens on which birds or insects are electroculated.

(c) Burning: The burning of locust adults or grass hoppers or blister beetles with the help of flame torches or flame throwers when the control measures ineffective.

Manipulation of physical factors:

(i) Application of heat:

(a) Super heating of empty godowns to a temperature above 50 º C for 10-12 hr will kill the hibernating stages of stored grain pests.

(b) When stored grains are exposed to sub-zero temperatures, the insects are killed.

(ii) Manipulation of moisture:

By raising or lowering the moisture content of food and other materials, unfavourable conditions are being created for the insect pests e.g. reducing moisture content of grain below 8% will make the stored grain pests unfit for consumptions of stored grain pests

Answer the following questions in brief.

1. Write advantages and limitations of mechanical control.

2. Mention the advantages and limitations of physical control.

3. What is concept of mechanical and physical control?

4. How will you follow the mechanical method for the management of following insect pests?

(i) *Spodoptera litura* in tobacco nursery/ transplanted crop

(ii) Pyrilla infesting sugarcane.

(iii) White grubs infesting groundnut.

(iv) Stem borer infesting mango.

(v) Yellow stem borer infesting rice.

(vi) Mealybugs infesting mango.

(vii) Bird’s infesting maize.

(viii) Anar butterfly damaging to pomegranate.

(ix) Armyworm in paddy.

(x) Bird damage in orchard crop.

(xi) *Helicoverpa armigera* in gram.

(xii) Locust infesting crops.

(xiii) Black headed gall forming caterpillar in aonla.

(xiv) Larvae of lemon butterfly infesting citrus.

(xv) Hispa and blue beetles in rice.

EXERCISE – 7
PRACTICABLE IPM PRACTICES, CULTURAL AND BIOLOGICAL METHODS

CULTURAL CONTROL

Cultural control of insect pests is through the manipulation of the environment in such a way so as to render it unfavourable to pest. Modification of cultural practices a great deal of ecological information about the pests if it has to be effective in pest control programme. The main object of the cultural control is to make the environment less favourable for pest and/or favourable for its natural enemies.

Advantages and disadvantages:

Advantages	**Disadvantages**
• Low cost	• Not always feasible
• Safety to non-targets	• Not always effective
• No toxic residues	• Yield slow results
• Non-polluting	---

Ecological base management: "Since cultural control manipulations are based on habitat management and component of the agro-ecosystem in which the pest thrive, this approach has also been called as Ecological management or environmental control".

Important cultural methods used in the management of insect pests:

Crop rotation: Crop rotation involves sequential planting of unrelated crop plants in normally a three to five year cycle. These practices normally reduce and delays the pest attack rather than giving complete control. Generally, crop rotation is most effective against pests that have a narrow host range and limited mobility. It is also effective in reducing many soil pests which multiply successfully under grasses e.g. Groundnut with non leguminous crop, paddy after wheat.

Period of sowing: The manipulation of sowing period helps in minimizing the pest's damage by producing asynchrony between host plant and the pest so that pest emergence fails to coincide with critical crop growth stage. The time of sowing alters the period of crop development to allow young plants to become established to a tolerant stage before attack occurs and thus reduces the susceptible period of crop before pest become abundant e.g. early planting of sorghum reduces the shoot fly infestation; early planting of mustard for the management of aphid.

Irrigation: Irrigation is a common practice in may crops and can be manipulated for pest control. Under condition of moisture stress, irrigation helps to minimize the effects of pest injury as the plants grow vigorously and thus compensate to some extent the loss of tissues due to pest feeding. Soil insects may be killed by pressure of swelling soil particles in saturated soils e.g. flooded of fields for the management of army worm, flood irrigation reduces the activity of termites.

Intercropping: It is intended for getting some return from area when one crop is attacked the other escape. The crops grown in an intercropping system will improve soil fertility and availability of alternative source of nutrients as well as reducing the incidence of insect pest e.g. cotton with black gram, green gram, castor, maize or pigeon pea.

Sanitation: This is one of the basic methods to eliminate pest overwintering sites and reduce the spread of infestation. Eradication of weed hosts, timely destruction of crop residues and removal of shelter in which insects harbour breaks the life cycle of insects e.g. brinjal crop residues and shoot & fruit borer, pink ball worm in cotton, Rice stubbles and stem borer.

Pruning: Pruning of dead branches, scraping of unhealthy stems, patching up wounds with clay and tar and removal of bark keep away the insects which hibernate or multiply in such places e.g. aonla gall forming infested shoots, citrus psylla.

Trap crops: Smaller planting made earlier than the main planting of crop may effectively be diverted the insect attack from the crop at risk by using more attractive crop. For the system, trap crop must be attractive to target pest and tolerate to heavy attack e.g. marigold trap crop for *H .armigera*, castor trap crop for *S. litura*.

Tillage: Ploughing and hoeing help to bury the stages of insects or expose stages of soil inhabiting insects to be picked up by birds e.g. pupae of *S. litura* and *H armigera*.

Fertilizer: Excessive use of organic nitrogenous fertilizers generally created congenial conditions for many insect pests. On the other hand, application potash and sometime phosphorus also either singly or in combination with nitrogen results in lower incidence of many insect pests e.g. recommended dose of nitrogen and sucking insect pest.

Harvesting practices: Harvesting practices involving crop maturity, time of harvest or cutting practices. Early harvest can often reduce losses from the pest damage e.g. fruit fly in mango, guava and other fruit crops.

BIOLOGICAL CONTROL:

Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition or biological control involves use and manipulation of natural enemies by man.

Parasite: A parasite is an organism which usually much smaller than its host and a single individual usually does not kill the host.

Parasitoid: A parasitoid is a specific kind of parasite which is often about the same size as its host, kills its host and requires only one host (prey) for development in to free living adults e.g. Braconids wasp.

Predator: A predator is free living organism throughout its life, it kills and prey, is usually larger than it s prey and require more than one prey to complete its development e.g. *Chrysoperla carnea*. Lady bird beetles, Syrphid fly, Spiders, *Spalgis epius, Chilocorus nigritus* etc.

Super parasitism: It is type of parasitism where more individuals of the same species are present in a single host and than can complete development in a normal way. Generally survive one per host e.g. *Diachasmimorpha longicaudata* (Ashmead) in fruit fly, *Trichogramma* spp in eggs of lepidopteran insects.

Multiple parasitisms: It is the type of parasitism where the host is attacked by two or more species of parasitoids. Usually death results in the death of less aggressive species of parasitoids e.g. *Horogenes chrysostictos* and *Nemeritis canescens* attacking on the larva of the moth, *Ephestia sericariu.*

Hyper parasitism: It is type of parasitism in which a parasitoid attacks another parasitoid. Secondary parasitoids are harmful, while tertiary useful e.g. species of chalcid and *Perilampus* are often parasitic on the ichneumonoid genera *Microgaster* and *Apanteles*, which are parasites of caterpillars of Lepidoptera.

Biological control practices involve three major techniques:

(i) Introduction: Import and release of predators/ parasites is known biological control through introduction. The newly introduced exotic pest can be managed by the importation of native natural enemies. Some time, local natural enemies may not able to control the pest and in this case, importation of parasites/ predators from the other location or place or country may work efficiently. Many International and National Organizations have been established to facilitate the movement of beneficial species from one country to another country. Cottony cushion scale infesting fruit crops in Tamil Nadu satisfactory managed by the introduction of Vedalia beetle, *Rodolia cardinalis* from California. Apple woolly aphid was effectively controlled by the introduction of parasitoid, *Aphelinus mali* from North America. Coconut black headed caterpillar managed by the introduction of parasitoid *Goniozus* in Tamil Nadu.

(ii) Conservation: Action to preserve and increase natural enemy by environmental manipulation is known as conservation. Not to be used those pest control measures which destroy the natural enemy. The conservation and enhancement of natural enemies should be considered first. If they are properly conserved, the need for other control measures is greatly reduced.

Important pest control measures for the conservation of natural enemies:

- Use of selective insecticides.
- Avoid the cultural practices which are harmful to natural enemies.
- Use of cultural practices which are favourable to natural enemies.
- Select variety, which is one favour to colonizing of natural enemies.
- Provide alternate host to natural enemies.
- Provision of food like pollen, nectar for adults of natural enemies.
- Provision of refugia for adults of natural enemies.
- Maintain male population of insect over extended period to ensure continued survival of natural enemies.
- Control of honeydew feeding ants.
- Preservation of inactive stages of natural enemies.
- Maintain plant diversity.

(iii) Augmentation: Augmentation includes all activities designed to increase number or effect of existing natural enemies. These may be achieved by releasing additional numbers of a natural enemy into a system or modifying the environment in such a way as to promote greater numbers or effectiveness. Augmentation differs from introduction in that these have to be repeated periodically.

Augmentation (periodic releases) includes:

(a) Inoculative releases: Releases of natural enemies infrequently, once a year to re-establish which is periodically killed due to unfavourable conditions. Expected control of pest is achieved from the progeny and subsequent generations and not from the releases itself.

(b) Inundative release: Mass culturing and releases of natural enemies to suppress the pest population directly as in case of insecticides e.g. six time releases of *Trichogramma* for the control of boll worm in cotton, two time releases of *Chrysoperla* for the control of bollworms.

Microbial Control: When microbial organisms or their product (toxin) are employed by man for the control of insects, animals and plants in particular area is referred as microbial control e.g. Virus (Baculoviruses, Polyhedrosis virus (NPV), Granulosis virus, Cytoplasmic virus), Bacteria (*Bacillus thurienginesis, B. popiellie*), Protozoa (*Mettaisa frogodermae*), Fungi (*Beaveria* spp., *Metarhizium* spp., *Verticillium* spp. *Nomureae rileyi*), Nematodes (DD-136, S*ternonema*) etc.

Advantages and disadvantages of biological control:

Advantages	**Disadvantages**
• Low cost	• Not always applicable
• Safety to non-targets	• Insufficient control
• No toxic residues	• High cost research activity
• Non-polluting	• Not solve the sudden problem
• Same as cultural methods	
• applicable to crop pests	
• Self-sustaining	
• Permanent & specific	

Answer the following questions:

1. Give the examples of insect pests to carry out the following cultural practices.
   - **(i)** Crop rotation
   - **(ii)** period of sowing
   - **(iii)** Irrigation
   - **(iv)** Intercropping
   - **(v)** Sanitation
   - **(vi)** Pruning
   - **(vii)** Trap crop
   - **(viii)** Tillage
   - **(ix)** Fertilizer

2. Name the ovipositional trap crop for leaf eating caterpillar, tomato fruit borer and diamond back moth (DBM).

3. How sanitation is useful in management of mealybug in cotton?

4. Write advantages and limitations of cultural control.

5. Give the important natural enemies of the following insect pests.

- Aphid:
- *Spodoptera litura*:
- Whitefly:
- White grub:
- Mealybug
- DBM:

6. Differentiate: Parasite and Parasitoids.

7. Name the techniques for biological control.

8. What is microbial insecticide?

9. Enlist different methods for the conservation of natural enemy.

10. Name microbial insecticides available in market.

11. Give one or two successful examples in biological control.

12. Visit farm and record the following observations:

(a) Name of the crop and variety: ____________ Crop stage: ___________

(b) Population of natural enemies:

Sr. No.	**Plant No.**	**Name and numbers of predator(s) per plant**		
		(i)	(ii)	(iii)
1				
2				
3				
3				
4				
5				
6				
7				
8				
9				
10				

(i) Predator: _________________ feeding on _____________.

(ii) Predator: _________________ feeding on _____________.

(iii) Predator: ________________ feeding on _____________.

13. Name the agencies/ companies who dealing in multiplication of natural enemies and marketing in Gujarat.

14 Visit a biological control laboratory and write a brief note on observed different natural enemies and multiplication of parasites/predators.

EXERCISE – 8
CHEMICAL CONTROL, INSECTICIDES AND THEIR FORMULATIONS

Pest management is the integration of suitable tools including spray application of insecticides to keep the pest population down to a reasonable level. Application of insecticides is the most powerful tool for the management of insect pests infesting various crop plants and it is most popular tool in the farming community. Under critical stage, this is the only tool that can be managed the population of pest. There are several form of formulations are available in the market

Formulations of insecticides:

After an insecticide is manufactured in a relatively pure form (technical grade), it must be formulated before it can be applied. Formulation is the processing of the technical grade by various methods which is done to make the product safer, more effective and more convenient to use. In a formulation, there are one or more chemicals (formulants) which are the active ingredients (a.i.) and other ingredients which have no pesticide action (inert ingredients). Inert ingredients may be toxic to the applicator irrespective of the fact that they have no pesticide action.

There are mainly three types of pesticide formulations (liquid, solid and gas). A single pesticide may be sold in more than one formulation. Some products are ready to use and require no further mixing. However, most products applied in the liquid form must be diluted in water or oil before use. Formulation type depends on several factors:

- toxicology of the active ingredient,
- chemistry of the active ingredient,
- how effective the product is against the pest,
- the effect of the product on the environment (plant, animal or surface etc.),
- how the product will be applied and the equipment needed the application rate.

Characteristics of an Appropriate Insecticides Formulation

- **Highly toxic to target insects.** Generally, with due course of time, target insects develop resistance to the insecticide and thus insecticide may lose their effectiveness. If resistance is observed another insecticide without cross-resistance has to be used.

- **Not repellent or irritant to target insects** to ensure that the insects pick up a lethal dose.

- **Long-lasting.** The toxicity should remain high over a sufficiently long period to prevent the need for frequent reapplication, which is costly and time-consuming.

- **Safe to humans and domestic animals.** There should be no danger to spray workers, inhabitants or animals accidentally contaminated with the insecticide during or after spraying.

- **Stable during storage and transportation.** Insecticides should be stable during storage and transportation.

- **Cost-effective.** Insecticide should be economical in terms of the money spent on it

Common Formulations:

1. **Dusts (D):** Dusts are the simplest of all formulations and the easiest to apply. To prepare a dust formulation, the toxicant is diluted either by mixing with or by impregnation on a suitable finely powdered carriers. e.g. methyl parathion 2%, quinalphos 1.5%, carbaryl 5%, chlorpyriphos 1.5%.

2. **Wettable Powders (WP) or Water Dispersible Powders (WDP):** Wettable powders are concentrated powder formulations containing a wetting agent to facilitate mixing the powder with water before spraying. The active ingredient in a wettable powder formulation ranges from 5 to 95 per cent. The dust particles when falling free in air either slowly settles down due to gravity or drift for long distance due to wind. The size and shape of particle is greatly influenced on rate of deposition on the target. Adequate humid condition enhances the orientation of particles towards the target. In general, there may be adverse effect on the population of natural enemies and environment consequences too e.g. carbaryl 50% WP.

3. **Water-Soluble Powders (SP):** Water-soluble powders contain a finely ground water soluble solid which dissolves readily upon the addition of water e.g. acetamiprid 20 SP and acephate 75 SP.

4. **Emulsifiable Concentrates (EC):** Most of the synthetic organic insecticides are insoluble in water but soluble in organic solvents. More than 75% of all insecticide formulations are applied as sprays and a majority of these are water emulsions prepared from emulsifiable concentrates (EC) e.g. quinalphos 25 EC, chlorpyriphos 20 EC, fenvalerate 20 EC, dimethoate 30 EC etc.

5. **Solution Concentrates (SC) or Water Soluble Concentrates (WSC):** When the technical-grade material is miscible with water or alcohol, it can be formulated into soluble concentrate or water soluble concentrate e.g. Monocrotophos 36 WSC.

6. **Oil Solutions:** Oil solutions are formulated by dissolving insecticide in an organic solvent for direct use in insect control. They are rarely used on crops because they cause severe burning on foliage. The concentrated solutions may be diluted with kerosene or diesel oil before application.

7. **Suspension Concentrate or Flowable (F):** Some insecticides are soluble neither in oil nor in water. In this case, technical material is wet-milled with a solid carrier diluents (like inert clay) and water with a suspending agent, a thickener and an anti-freeze compound, thus forming a thick creamy pudding like mixture which mixes well with water but needs frequent agitation e.g. Spiromesifen 240 SC.

8. **Aerosols:** Aerosols are the most common of all formulations used in indoor application. The toxicant is suspended as minute particles (0.1 to 50 microns) in air as a fog or mist. To produce an aerosol, the active ingredients must be soluble in volatile petroleum oil under pressure. The pressure is provided by a propellant gas. When the solvent is atomized, it evaporates readily, leaving behind small droplets of the insecticide suspended in air. e.g. propoxur, tetramethrin, resmethrin, allethrin etc.

9. **Granular (G):** The granular formulation is composed of a base made of either inert material or vegetable carrier (like maize cob) with the active ingredient fused with it e.g. phorate 10 G, carbofuran 3 G, cartap hydrochloride 4 G

10. **Fumigants:** Chemical fumigants are gases or volatile liquids of low molecular weight which readily penetrate the material to be protected. e. g. Aluminium phosphide, methyl bromide

11. **Ultra-Low Volume Concentrates (ULV):** These formulations usually contain a technical product dissolved in a minimum amount of solvent. They are applied without further dilution by aerial or ground equipment in volumes of 0.6 litre to a maximum of 4.7 litre /ha.

12. **Fogging Concentrates:** These are used in the control of adult flies and mosquitoes and sold for public health use to pest control operators. Fogging machines generate droplets of 1-10 µ.

13. **Poison Baits:** Formulated baits contain low levels of toxicants incorporated into materials such as food-stuffs, sugar, molasses etc. that are attractive to the target pest e.g. poison bait containing carbaryl + wheat bran + jaggary for the control of *S. litura* and dichlorvos + jaggary or protein hydrolysate + water for the control of fruit fly.

14. **Oil dispersion (OD):** The oil dispersions (ODs) formulation is very efficient and environmentally friendly agrochemical. In ODs the solid active ingredient is dispersed in the oil phase, making it especially suitable for water-sensitive or non-soluble active ingredients. When the oil dispersion comes into contact with water, the formulation can either form an emulsion or a suspension emulsion. The oil-phase can comprise different oils such as mineral oils, vegetable oils or esters of vegetable oils. Special attention is needed with the auxiliaries in ODs: suitable oil-compatible dispersing agents and emulsifiers adjusted to the type of oil which form a stable emulsion after dilution with water e.g. cyantraniliprole 10 OD.

15. **Soluble liquid (SL):** Active ingredients which dissolve readily in water can be formulated as soluble liquids (SL). To achieve a better wetting on plant leaves, additional wetting agents can be added to the concentrate. The biological performance is further improved by using adjuvants e.g. Phosphamidon 40 SL.

16. **Water dispersible granules (WG):** Water dispersible granules (WG) have more and more substituted wettable powders (WP) due to their reduced inhalation hazard during handling. However, a higher amount of wetting and dispersing agents is required since the easy and quick formation of a suspension after dilution of the granules with water is crucial e.g. Thiamethoxam 25 WG, Clothianidin 50 WG, Imidacloprid 70 WG etc.

17. **Flowable suspension for seed treatment (FS):** This type of formulation is used for film-coating or pelleting of seeds. To avoid adverse effects, users should apply the formulation strictly according to the recommendations and should not treat seeds for which effect on germination is not known. Treated seeds should be stored in a suitable container and should be protected from excessive temperature and moisture e.g. Thiamethoxam 35 FS, Imidacloprid 600 FS.

18. **Capsule suspension (CS):** Capsule suspensions are among the next generation of formulations, allowing active ingredients to be released gradually over a prolonged period of time e.g. Pendimethalin, a herbicide

Pesticide application methods:

The pesticide application method depends on the nature and habits of the target pest, the characteristics of the target site, properties of the pesticide, suitability of the application equipment and cost as well as efficiency of alternative methods. The different methods of application of insecticides are discussed here briefly.

i. **Seed Treatments:** Application of insecticide to seeds before or at the time of planting offers the most efficient and concentrated means of protecting the germinating seeds and seedlings. Such applications are minimal in dosage and therefore, highly economical as well as least disturbing to the environment e.g. Imidacloprid 600 FS, thiamethoxam 35 FS

ii. **Seedling dip method:** The whole seedling or seedlings root dip method found effective for the control of stem borers, gall midge and whorl maggot infesting various crops. The method is also selective and safe to the natural enemies e.g. paddy seedling root dipped in chlorpyriphos solution for the control of stem borer .

iii. **Root zone placement method:** Root zone placement also known as deep placement or band placement. This method reduces the quantity of insecticides applied. A systemic insecticide packaged in capsules and placed in the root zone controlled common insect pests. This method is cheaper and more effective.

iv. **Whorl application:** Whorl application of insecticides has been found effective for number of insect pests feed on whorl. Application of granular insecticide in whorl for the control of larvae feeding on whorl or in the stem e.g. maize stem borer control.

v. **Electrostatic Spraying:** The ULV spinning disc sprayer used as an electrostatic charge to produce spray droplets. The Electrodyn sprayer was invented by Coffee in 1970. The commercially available Electrodyn sprayer can be used with pesticide prepacked in a plastic container with nozzle, as an integral part of it to form Bozzle. This Bozzle is screwed into the long tubular stick that contains four 1.5 VD size batteries and a high voltage generator. The nozzle is charged and subsequent space cloud effect creates and on both upper and lower surface of leaves, stem and other parts of the crop canopy.

vi. **Chemigation:** It is the application of agrochemicals by injection in to the water flowing through an irrigation system. Chemigation is possible with all type of irrigation *i.e.* through drip or sprinkler or flood or furrow. The minimum equipments require for application of insecticides through chemigation. In flood and furrow irrigation, a constant head siphon device can be used instead of an injection pump to meter a chemical into water.

vii. **Infusion and Injection method:** Infusion and injection are environmentally safe techniques for introducing pesticide in xylem tissue of fruit and ornamental plants.

viii. **Attract and kill device:** A promising approach for arthropod control is the developed as attractant and killing devices. For example, polyvinyl chloride (PVC) has been used to combine and slowly release a mixture of grand lure (sex and aggregating pheromone for the boll weevil), feeding stimulants and toxicants for the control of boll weevil.

ix. **Fumigants:** A fumigant is a gaseous poison used to kill insect pests, nematodes, rodents etc. and its application is limited to live plants or products in tight enclosures or to soil. Fumigants are also employed to control a great variety of pests of stored products, household articles, etc.

x. **Foliar application:** This method is most popular in the farming community for the application of insecticides spraying through sprayers or dusting through dusters.

xi. **Spot application:** Insecticide can be applied when limited plants in the field are infested with the pest. Thus, it can be minimized unnecessary application of insecticides on plants those not affected by insect pests at all e.g. Termite control, mealy bugs, application of poison bait for the control of fruit fly in orchard and cucurbitaceous vegetables etc.

xii. **Stem application:** When the activity of the pests *i.e.* scales, mealybug, vine borer is limited only on the stem, a paste of insecticide e.g. carbaryl 50 WP can be used. Spray of synthetic insecticide only on the tree trunk of mango during October-November greatly minimized hibernating stage of mango hopper.

xiii. **Aerosol:** Aerosol applicators are designed to reduce small droplet suspension into the air to control flying insect such as mosquitoes and flies. Insecticides dissolve in an organic solvent and packed in a pressurized container with petroleum gas as propellant.

xiv. **Application through aircraft:** In case of outbreak of the insect pests and require to cover large area in a limited time, the application of insecticides through air craft's/ Helicopters are most important tools. However, adverse affect on the natural enemies and contamination of environment may be.

Advantages of insecticides:

i. It is the only practical method of pest control when pest population is close to economic threshold. It is an emergency intervention when all other pest control methods are failed.

ii. Insecticide has rapid action property in reducing pest population. Contrary to biocontrol agents that take long time for suppression of pest population, insecticides rapidly kill the pest's population.

iii. It has wide range of activity on insect pest. From the large numbers of chemicals, one can choose according to need. Some of the chemicals are long persistence and short residual action. Now a day's highly selective chemicals those with range of activity against several pests are available with contact, fumigant and systemic action. Soil insecticides are chemicals that remain active in soil for a long time. The chemicals those active against pest organisms are nematicides (nematodes), miticides (mites), rodenticides (rodents) and weedicides (weeds).

iv. Cost/benefit ratio is favourable with insecticides. Insecticides are relatively inexpensive deplaning upon the number of steps involved in their synthesis.

Limitations of insecticides:

i. Insect pests may create resistance against insecticides.

ii. Resurgence of minor pests.

iii. Residues of insecticides.

iv. Adverse effect on non target pests and environment

Answer the following questions:

1. Give the name of insecticide for the following groups:

Sr. No.	Name of the groups	Name of insecticides with its concentration
01	Carbamates	
02	Organochlorine	
03	Organophosphate	
04	Ketoenol	
05	Synthetic pyrethroids	
06	Neonicotinoids	
07	Growth inhibitors	
08	Pyrozol	

09	Quinalzolin	
10	Organo sulphur	
11	Neristoxin	
12	Phenyl pyrozol	
13	oxadiazine	
14	Non ester pyrethroids	
15	Thio-urea	
16	Pyridyl	
17	Benzene diacarboximide	
18	Anthranilamide	
19	Based on bacteria	
20	Fermentation based	
21	Bio-pesticides	
22	Neem based formulations	
23	Desiccant insecticides	

2. Name the most effective and popular insecticides/pesticides for the control of following insect pests.

Sr. No.	**Name of the pests**	**Name of the insecticides with its recommended dose**
01	Sucking insect pests	
02	Chewing types insects	
03	Mealybugs	
04	Scale insects	
05	Maize stem borer	
06	Paddy stem borer	
07	Thrips	

08	Diamond Back Moth	
09	Army worms	
10	Slugs and snails	
11	Cotton bollworms	
12	Soil inhabitant insects	
13	Mites	
14	White grubs	
15	Termites	
16	Stored grain insect pests	
17	Gujarat Hairy caterpillar	
18	Grass hoppers	
19	Paddy leaf hoppers	
20	Fruit fly	
21	Ovicides	
22	*Spodoptera litura*	

3. What are major the limitations/ disadvantages of chemical control?

4. Enlist different insecticidal application methods with examples.

5. Why synthetic insecticides are the most popular in farming community?

EXERCISE – 9
CALCULATION OF DOSES/CONCENTRATIONS OF INSECTICIDES

The insecticides available in the market contain different percentage of active ingredient e.g. deltamethrin 2.8 EC, carbaryl 50 WP, dimethoate 30 EC, triazophos 40 EC, acephate 75 SP, thiamethoxa m 25 WG etc.

Insecticides are recommended in two ways.

i. On the basis of concentration of insecticide in spray fluid e.g. dimethoate 0.03%, monocrotophos 0.04%, carbaryl 0.2%.

ii. On the basis of a.i. /ha e.g. dimethoate 300 g a.i. /ha, carbaryl 2 kg a.i. / ha.

Thus, it is necessary to work out the quantity of formulated insecticide to be mixed in given quantity of water to obtain a desired concentration of insecticide in the spray fluid.

I. On the basis of concentration of insecticides in spray fluid:

$$\text{Quantity of insecticide required (kg/l)} = \frac{\text{Quantity of spray fluid to be prepared (l)} \times \text{Concentration of spray fluid (\%)}}{\text{Concentration of a.i. in the formulation (EC/WP/SC)}}$$

Example: Groundnut crop is infested with aphid, *Aphis crassivora* at vegetative stage. Farmer is advised to spray monocrotophos 40 EC @ 0.04% two times at an interval of 10 days. He has cultivated groundnut crop in three hectares. The prevailing market price of insecticide is Rs. 350/ litre. Total 300 litres water require for proper coverage of the crop. Generally, two labours are required to spray one hectare of crop. The prevailing labour charge is Rs. 150/ labour/day.

Calculation:

$$\textbf{Quantity of insecticide in one litre of water} = \frac{\text{Quantity of spray fluid} \times \text{Concentration of spray fluid (\%)}}{\text{Concentration of a.i. in the formulation}}$$

$$= \frac{1 \times 0.04}{40}$$

$= 0.001$ litre *i. e.* 1 ml/ litre

Quantity of insecticides for 300 litre	=	Quantity of insecticide in one litre	×	Total water required				
	=	1 ml	×	300 litres				
	=	300 ml						
Total Quantity of insecticide for total spray	=	Area to be spray (ha)	×	No. of Spray(s)	×	Quantity of insecticide (ml/l)	×	Water require per spray (l/ha)
	=	03	×	2	×	1	×	300
	=	1800 ml *i e*. 1.8 litres						
Total labour Charge(Rs.)	=	No. of labour require/ha per spray	x	No. of Spray(s)	×	Labour charges (Rs. /labour)	×	Total area cultivated (ha)
	=	02	×	02	×	150	×	03
	=	Rs. 1800						
Total cost of insecticides (Rs)	=	Price of insecticides (Rs. / l or kg)	×	Total required insecticides (Formulation)				
	=	350	×	1.8				
	=	Rs. 630						
Total cost of plant protection (Rs)	=	Total cost of insecticides (Rs)	+	Total labour charges (Rs.)				
	=	630	+	1800				
	=	Rs. 2430 for three hectare area and two sprays						

I. On the basis of a.i. per hectare:

Quantity of insecticide (formulation) per hectare (litre or kg) $= \dfrac{\text{Recommended a. i. /ha (g or kg)}}{\text{a.i. present in formulation}} \times 100$

Example: A chilly grower of padra, District Vadodara is interested to apply carbofuran @ 1 kg a. i. /ha at the time of transplanting and 30 days later for the control of thrips. He has to pay Rs. 120/- for purchase of one kg of carbofuran (formulation /granules). He has planned to cultivate this crop in three hectares. One labour is required for soil application of carbofuran. He has to pay Rs. 200/- to one labour.

Quantity of insecticide (g or kg/ha) $= \dfrac{\text{Recommended a. i. /ha (g or kg)}}{\text{a.i. present in formulation}} \times 100$

$= \dfrac{\text{1 kg a. i ./ha} \times 100}{3}$

= 33.330 kg for one hectare carbofuran 3G

Total Quantity of insecticide for all applications = Area cultivated(ha) × No. of application(s) × Quantity of insecticides (formulation) (g or kg / ha)

= 03 × 02 × 33.300

= 199.98 kg *i.e.* 200 kg

Total Quantity Labour Charge (Rs.) = No. of labour required/ ha per application × No. of application(s) × Labour charges (Rs. /labour) × Total area cultivated (ha)

= 01 × 02 × 200 × 03

= Rs. 1200

Total cost of insecticides (Rs)	=	Price of insecticides (Rs. / kg)	×	Total required insecticides (Formulation)
	=	200	×	120
	=	Rs. 24000 for 3 ha area of chilly and two applications.		
Total cost of plant protection (Rs)	=	Total cost of insecticides (Rs)	+	Total labour charges (Rs.)
	=	24000	+	1200
	=	Rs. 25200/-		

Calculate the following examples:

Example 1: Paddy grower of Navli, District Anand is interested to apply cartap hydrochloride @ 1 Kg g a. i. /ha at one week after transplanting of the crop and one month later for the control of paddy stem borer, leaf roller and sucking pests. He has to pay Rs. 150/- for purchase of one kg of cartap hydrochloride (granules). He has planned to cultivate this crop in five hectares. One labour is required for soil application of cartap hydrochloride per hectare. He has to pay Rs. 150/- to one labour.

Calculate the example and fill up the following information:

i. How much quantity of cartap hydrochloride, he has to purchase from the market? ____ Kg.

ii. How much amount, he has to pay to the dealer/ retailer? ________ Rs.

iii. Write the total labour charges, he has to pay: __________________ Rs.

iv. Give the total cost of plant protection charges: __________________Rs.

Example 2: Chickpea crop is infested with pod borer, *Helicoverpa armigera* at pod formation stage. Farmer is advised to spray fenvalerate 0.02% two times at an interval of 10 days. He has cultivated chickpea crop in three hectares. The prevailing market price of insecticide is Rs. 400/ litre. Total 400 litres of water require for proper coverage of the crop. Generally, two labours are required to spray one hectare of crop. The prevailing labour charge is Rs. 160/ labour/day.

Calculate example and fill up the following information:

i. How much quantity of fenvalerate (formulation), he has to purchase from the market? ______________________________ litres

ii. How much amount, he has to pay to the dealer/ retailer?________ Rs.

iii. Write the total labour charges, he has to pay: ________________ Rs.

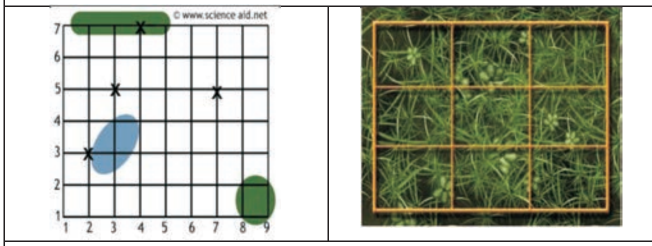
iv. Give the total cost of plant protection charges: _______________Rs.

NOTES

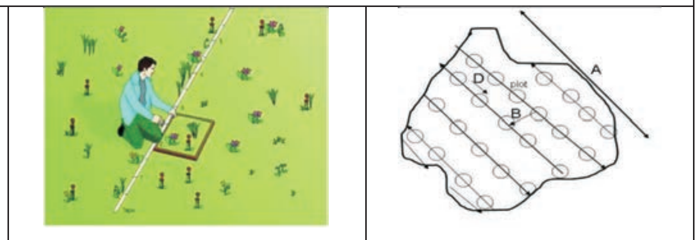
NOTES

PLATE 1: SAMPLING TECHNIQUES FOR ESTIMATION OF INSECT POPULATION AND DAMAGE

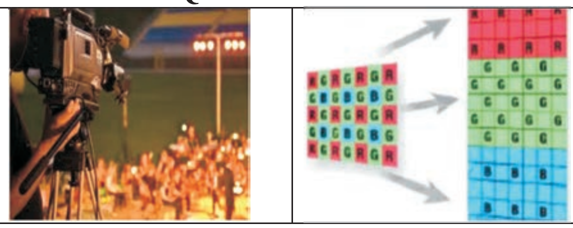
Methods of absolute estimates



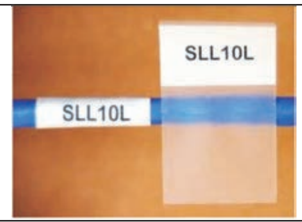
Quadrate method



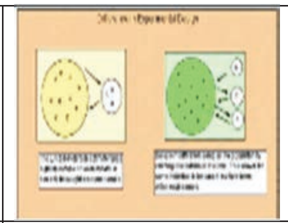
Line transect method



Capture method



Marking release



Recapture method

Flying trap

Pheromone trap

Netting

Aquatic traps

Pitfall trap

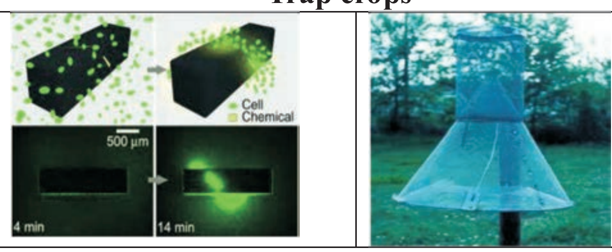
Light trap

Fennel trap

Attractant trap

Trap crops

Bait trap



Chemical attractants

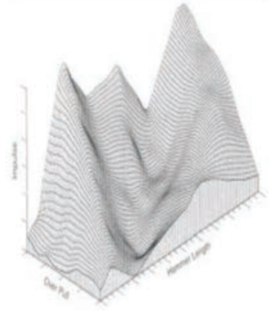
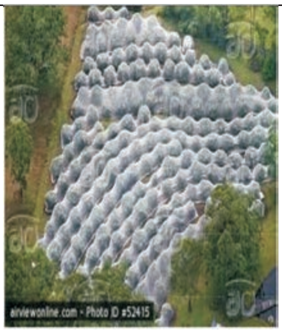
Methods of absolute estimates			
			
Jarring	**Chemical**	**Heating**	**Sweep netting**
			
Netting		**Vacuum netting**	
			
Aerial netting		**Winged pheromone**	
Light trap			
			
Common light trap	**UV light trap**	**Florescent light trap**	

PLATE 3: PRACTICABLE IPM PRACTICES: PHYSICAL AND MECHANICAL METHODS


Hand picking


Hand nets


Bag nets


Beating


Hooking


Shaking


Jarring


Banding


Plastic ribbon


Trenching

PLATE 4: PRACTICABLE IPM PRACTICES: PHYSICAL AND MECHANICAL METHODS


Bird Scarer


Burning


Clipping

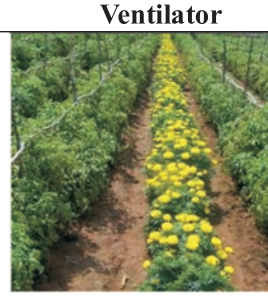

Sieving


Winnowing

Ventilator

Barrier


Wrapping of fruits




Trap crops


Light trap

Air suction trap

Electric trap

PLATE 5: PRACTICABLE IPM PRACTICE: CULTURAL AND BIOLOGICAL METHODS

Cultural Methods

Crop rotation

Time of sowing

Irrigation

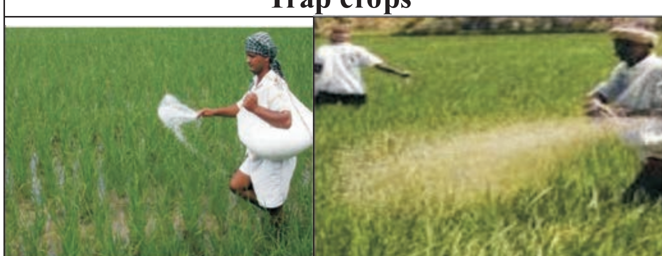
Intercropping

Sanitation

Pruning

Trap crops

Tillage



Fertilizer

Harvesting practices

Removal of weed hosts

Destruction of crop residues

PLATE 6: PRACTICABLE IPM PRACTICE: CULTURAL AND BIOLOGICAL METHODS

Biological Methods

Parasitoids

Trichogramma spp.

Telenomus spp.

Apenteles spp.

C. chloridae

Lady bird beetle

Cryptolaemus spp.

Chrysoperla spp.

Syrphidfly

Reduvid bug

Dragonfly

Mantid

Spiders

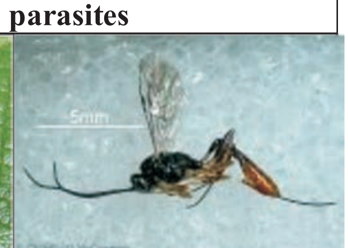
Super parasites

Diachasmimorpha spp.

Tichogramma spp.

Multiple parasites

Diadegma spp.



N. cenescenes

Hyper parasitoids

Chalsid spp.

Perilampus spp.

Augmentation

Inoculative release

Innudative release

PLATE 7: PRACTICABLE IPM PRACTICE: CULTURAL AND BIOLOGICAL METHODS

Entomophage park

Microbial control

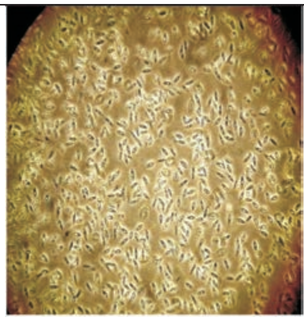
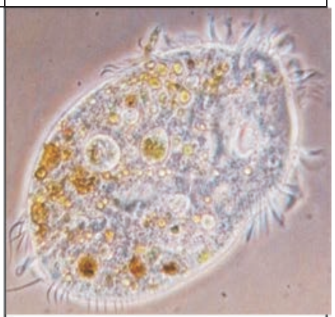
			
Nuclear polyhedrosis virus		**Cytoplasmic PV**	**Granulosis virus**
			
Bacillus thuringiensis	***Bacillus thuringiensis***	***Bacillus poppilae***	**Protozoa**
			
Heterorhabditis spp.	***Beauveria bassiana***	***Metarhizium anisopliae***	***Lecanicillium lecanii***

PLATE 8: CHEMICAL CONTROL, INSECTICIDES AND THEIR FORMULATIONS

Formulations of insecticides

Dust

Granular

Wettable Powders

Water-Soluble Powders

Emulsifiable Concentrates (EC)

Suspension Concentrate (F)

Aerosols

Methyl Bromide

Liquid formulation

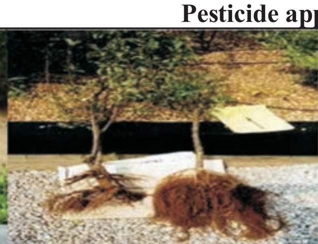
Fogger

Poison Baits

Capsule suspension

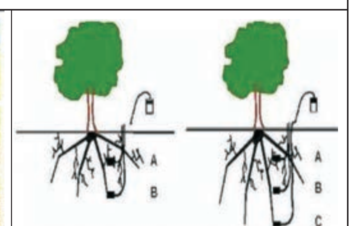
Pesticide application methods

Seed Treatments



Seedling dip method

Whorl application



Root zone placement

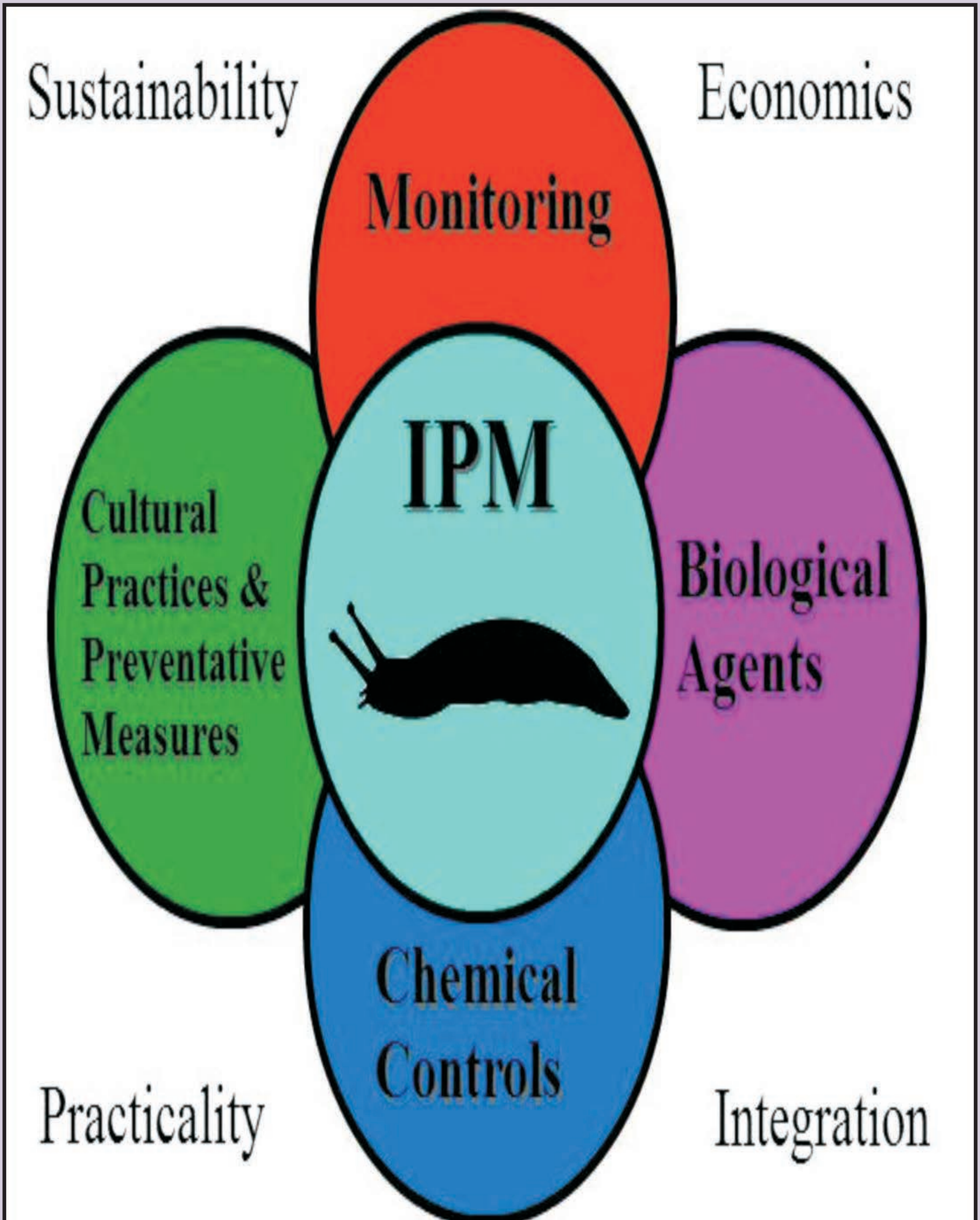
Pesticide application methods

Foliar application

Chemigation

Injection method

Application through aircraft

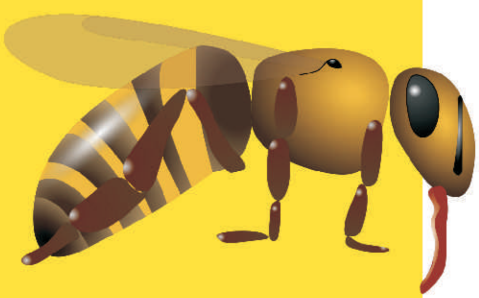

Sustainability
Economics
Monitoring
IPM
Cultural Practices & Preventative Measures
Biological Agents
Chemical Controls
Practicality
Integration

NAVSARI AGRICULTURAL UNIVERSITY

PRACTICAL MANUAL

Ag. Ento. 4.3 (1 + 1)
MANAGEMENT OF BENEFICIAL INSECTS

Fourth Semester B. Sc. (Hons.) Agriculture



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Apis dorsata

Apis cerana indica

Apis florea

Apis mellifera

NAVSARI AGRICULTURAL UNIVERSITY

PRACTICAL MANUAL

Ag. Ento. 4.3 (1 + 1)
MANAGEMENT OF BENEFICIAL INSECTS

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FOREWARD

A new course on "**Management of Beneficial Insects"** has been planned in agricultural universities at undergraduate level as per the course framework laid out by the Fifth Deans Committee recommendations of ICAR. The 36th Academic Council meeting of Navsari Agricultural University, Navsari was held on 25th April, 2017 with an item note No. 36.05 and the said council had approved the Fifth Deans Committee recommendations from the year 2017-18 along with the detail distribution of courses in NAU, Navsari.

It is a matter of immense pleasure that the "**Management of Beneficial Insects**" manual is being published by the Department of Entomology, College of Agriculture, Navsari Agricultural University, Waghai for the assistance of agriculture students. The manual contains applied knowledge and practically useful information on maintenance and care of productive insects like honey bee, silkworm, lac insect and biocontrol agents *viz*., predators and parasitoids of crop pests.

This practical manual has prepared and compiled by **Dr. J.J. Pastagia, Prof. D.M. Damasia and Mr. H. R. Kachhela** highlights all practical aspects. Authors have made joint efforts to collect and present the available literature in a comprehensive manner so as to be useful to the undergraduate students. The efforts of the authors of this manual are commendable and needs sincere gratitude. The language of manual is simple and easy to understand.

I pass on good wishes to the authors for bringing out this ample and useful practical manual to the students and the faculty members not only of this University but also to the students of Entomology of the nation.

(J. J. Pastagia)
Principal

Date: 1st March 2020
Place: Waghai

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
Waghai– 394730, Dist-Dang (Gujarat)

CERTIFICATE

This is to certify that Mr./Ms.____

Reg. No.________________ has completed practical exercises for **Fourth semester** B.Sc. (Hons.) Agriculture in the course No. **Ag. Ento. 4.3 Management of Beneficial Insects** Credits: **1+1** during the academic year ___________.

He/She has completed ________ practical exercises out of **twelve**.

University Seat No. ___________

Course teacher

Head of the Department

External examiner

INDEX

EXERCISE NO. 1

HONEY BEE SPECIES AND THEIR CASTES

Date:

Objectives:

1. To study the biology of honey bee.
2. To study the casts of honey bee.
3. To study the important species of honey bee.

I.	**Biology/ Life history of Honey bee**
1.	**Eggs:** Eggs are laid by queen and when a colony wants to produces a new queen, the special cell constructed at the lower border of the brood comb. In this cell, single egg is laid by the queen in each cell which hatched after 3 days. The newly hatched grubs are provided with royal jelly. The grub is fully developed in 5 to 6 days and then queen cell is capped where grub changes in to pupa and after a week adults come out by biting the cap of queen cell. The adult which comes out earlier become the queen daughter and it kills the remaining pupae before their emergence.
2.	**Nuptial flight:** After 2-3 days the queen daughter takes nuptial flight accompanied by hundreds of drones during day. She overtakes her in flight. The drone which follows her takes the chance of copulation. The male soon dies after copulation and the mated queen return to the comb. It mate only once in her life time. The seminal fluid (male sperms) is collected in a special receptacle (spermatheca) and used when required.
3.	**Oviposition:** After some times the queen daughter starts eggs laying and called as queen mother. She lays fertilized or unfertilized eggs at her will. The eggs are long, oval and light brown in colour. They hatch in 3-4 days.
4.	**Grub:** From the fertilized eggs, the queen and worker developed and from the unfertilized eggs drones are developed. The grub are cylindrical and light yellow in colour, they fed with the royal jelly for 2-3 days after that they are provided with honey and nectar, etc. The grub period lasts for 5-6 days.
5.	**Pupa:** Full grown grub forms a cocoon and pupates insides the cell. The pupal periods lasts 7-14 days depending upon the type of adult to be produced. The time required for development of different castes of *A. mellifera* is given below:

Adult	Eggs	Grub	Pupa	Total
Queen	3 days	6.5 days	6.5 days	16 days
Worker	3 days	8.0 days	10.0 days	21 days
Drone	3 days	9.5 days	11.5 days	24 days

6. Total lifespan/biology of honey bee:

Development Stage	**Caste**		
	Queen	**Worker**	**Drone**
Egg	3 days	3 days	3 days
Unsealed stage	5 days	5 days	7 days
Cell sealed	8^{th} day	8^{th} day	10^{th} day
Cocoon formation	10^{th} day	11^{th} day	14^{th} day
Adult formation	15^{th} day	20^{th} day	22^{nd} day

Adult emergence	16th day	21st day	24th day
Sexual maturity	within 2-3 days	-	13th days
Adult longevity	3-4 years	6 weeks	2-3 months

II. Honey bee castes:

The honeybee is a social insect and lives in colonies with a highly organized system of division of labour. Many combs are found in a colony in which the members of the same family used to live. Each family consists of three castes: queen (fertile female), drones (males) and workers (sterile females). Each caste has its special function in the colony. The workers are undeveloped females, the drones are known as males and the queen is the fully developed female. Every honey bee colony comprises of 35000 to 70,000 members includes a queen, 200 – 300 drones and several thousand workers.

A. Queen:

The queen, a true mother bee, is the only female that is completely developed sexually from fertilized egg. This is a result of a total diet of royal jelly fed during a developmental period. It has a long abdomen extending well beyond the apical margins of the wings. In the colony, she is found in the area of the brood nest. A well developed queen is generally two to three times bigger than a worker and measures about 15-20 mm in length.

Duties of a queen: The only individual which lays eggs in a colony (Mother of all bees). It lays eggs upto 2000 /day in *Apis mellifera* and maintaining a populous colony. Five to Ten days after emergence, she mates with drones in one or more nuptial flights. When her spermatheea is filled with sperms, she will start laying eggs and will not mate any more. She lives for 3 to 4 years and when it is weak or unable to lay eggs it is replaced by one of the daughter queen. The secretion from mandibular gland of the queen is called queen's substance. The queen substance if present in sufficient quantity performs following functions.

a) Prevent swarming and absconding of colonies.
b) Prevent development of ovary in workers.
c) Colony cohesion is maintained.

The queen can lay either fertilized or sterile eggs depending on the requirement.

B. Drone:

Drones, the functional males of the colony and these are produced from unfertilized eggs and larger and darker than the worker. It is smaller than queen and measures about 15-17 mm in length. Drones are not a permanent member of colony. The queen can control whether or not the egg is fertilized as she lays it. The compound eyes are holoptic i.e. very large and are united at the vertex. The end of the abdomen is blunt and is covered with a tuft of small hairs. As the sting is a modified structure of the female genitalia, drones do not have stings. They also do not have any of the structures necessary to collect nectar and pollen. It dies after successful mating with the queen.

Duties of a drone:

1. Their important duty is to fertilize the queen.
2. They also help in maintenance of hive temperature.
3. They cannot collect nectar / pollen and they do not possess a sting.

C. Workers:

Workers are sexually sterile female caste and is the smallest in size as compared with the above two castes. On ventral side of the abdomen, wax glands are present. Hind legs are modified for pollen collection. The mandibles are flattened and spoon shaped which are used for molding the wax for comb building. They do the work of the colony and maintain it in good condition. Workers have special structures and organs which are associated with the duties they perform.

Duties of a worker: Their adult life span of around 6 weeks can be divided into

i) First three weeks- house hold duty.
ii) Rest of the life- out door duty.

(a) House hold duty includes:

a. Build comb with wax secretion from wax glands.
b. Feed the young larvae with royal jelly secreted from hypopharyngeal gland.
c. Feed older larvae with bee-bread (pollen+ honey)
d. Feeding and attending queen.
e. Feeding drones.
f. Cleaning, ventilating and cooling the hive. g. Guarding the hive.
h. Evaporating nectar and storing honey.

(b) Outdoor duties:

1. Collecting nectar, pollen, propolis and water.
2. Ripening honey in honey stomach.

Schedule of a worker bee in the hive

Days after emergence	Task
1–2	Clean cells and warm the brood nest
3–5	Feed older larvae with honey and pollen
6–10	Feed younger larvae with products of the head glands
11–18	Ripen nectar, produce wax and construct comb
19–21	Guard and ventilate the hive, take exercise and orientation flights to learn to fly and locate the hive
22 +	Forage for nectar, pollen, water or propolis

III. Different species of bees and their important characters:

There are five important species of honey bees as follows.

1. The rock bee or giant bee, *Apis dorsata* Fabricious:

1. It is largest of the honey bees and measuring about 20 mm in length.
2. It construct single comb of huge size in open (About a meter in diameter)
3. The comb is fully exposed and hung from inaccessible branches of trees, along sides of steep rocks in the forest and even from the walls, rafters and other parts of buildings.
4. It produces plenty of honey i.e. 37 Kg honey /comb/year.
5. It represents a major portion of honey sold in our markets.
6. Rock bees are irritable and ferocious in nature and difficult to rear.
7. They shift the place of the colony often. In winter, they migrate to plains and come back to hills during summer season.

2. Indian hive bee/Asian bee, *Apis cerana indica* Fabricious:

1. It is common Indian bee found in both forest as well as in plains throughout country.
2. It is smaller than the rock bee but the larger than the little bee. Bee measures about 15 mm in length.
3. They make multiple parallel combs on trees, cavities, caves in darkness and such other hidden sites, the combs being parallel to the direction of the entrance in the plains and the right angle to the entrance in cold regions.
4. It is mild and capable of being domesticated and is commonly reared in south India.
5. They produce about 2 - 5 Kg of honey/ colony/ year.
6. A queen can lay 350 – 1000 eggs per day.
7. They are more prone to swarming and absconding.
8. They are native of India/Asia.

3.	**The little bee, *Apis florea* Fabricious:** 1. It is known as the little bee since it is smallest of the four species of Apis. Bee measures about 7 mm in length. 2. It is seen only in the plains and not in hills above 450 M. 3. It does not like darkness therefore forms its comb in the open place e.g. bushes, hedges, buildings, caves, empty cases etc. 4. It builds a single comb which is very small and produces about 0.5 to 1 kg honey/ hive/ year and so it is not domesticated and reared. 5. A queen can lay 323 – 365 eggs per day. 6. They are not rearable as they frequently change their place.
4.	**European bee or Italian bee, *Apis mellifera* Linnaeus:** 1. It is extensively reared in Europe and America. 2. The behaviour and appearance of *A. mellifera* is similar to *A. cerana*. 3. It makes its nest in enclosed space (in darkness) in multiple parallel combs and is endowed with all the good qualities of a hive bee, i.e. has a prolific queen, swarms less, gentle tempered so, domesticable, good honey gatherers and can guard its nest against enemies. 4. They yield on an average 45-180 Kg honey/hive/year 5. They are larger than Indian bees but smaller than Rock bees.
5.	**Dammer bee or stingless bee, *Trigona irridipennis* Dal. (*T. laeviceps*):** 1. This is the smallest species and differs from other bees in its appearance and habitats. 2. They do not have sting *i.e.,* stingless. 3. They built their comb in hollow walls or tree trunks. 4. They construct their comb with a dark material called "Cerumen" which is a mixture of earth and wax or resin collected from plants as they do not secrete wax to build combs. 5. It is very poor honey gatherers and yields only 60-180 ml/colony/year. 6. Its honey is used in *Ayurvedic* medicine.

Answer the following questions:

1. What are the different species of honey bees occurring in India?
2. What are the specialized structures or adaptations that make the honey bee as one of the most successful insects in the world?
3. What are the important modifications in the legs of worker bees?
4. Give the alternate names for the following: (a) Rock bee (b) Dammer bee (c) European bee (d) Asian bee
5. Differentiate the following: (a) Indian bee Vs Italian bee (b) Queen Vs Drone
6. How many years queen is living?
7. Which cast/s of bee is/are developed from fertilized egg and unfertilized egg?
8. What you understand by nuptial flight?
9. Give the function of queen substance in a colony.
10. Which species of the bees have gained the status of commercial beekeeping in India?
11. Which honey is having *Ayurvedic* medicinal values?

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EXERCISE NO. 2
BEE KEEPING EQUIPMENTS

Date:

Objectives:

1. To study the commonly used beekeeping hives for commercial beekeeping.
2. To study the various beekeeping equipments and accessories used in apiculture.
3. To give the exposure visit to students at beekeeping unit.

Apiary is the place where the honey bees are reared for honey and wax either commercially or as a hobby. Often a bee keeper is left with no choice for location of his hives, when he intends to keep them in his backyard or a small home garden. But where a selection among many possible sites can be exercised, the following points.

Requirements for site selection for apiary

- Apiary should be located where there is abundance of nectar and pollen yielding plants within the radius of one to one and half kilometer.
- The site should not be exposed to strong winds or at least the hives should not face the direction of the prevailing winds. Trees and bushes may be provided to make the site less windy.
- The site should be flat but with good drainage facilities.
- Clean and fresh running water should be available to the bees in or near the apiary.
- A young orchard is an ideal choice.
- If the site is shadeless and exposed, an artificial shade may be provided.
- An apiary should not be located too near highways.
- A good barbed wire fence or live hedge may be provided to keep out intruders.
  The site should be free from termite and black ant infestation.

I. Bee hives: Various types of bee hives are available for beekeeping. They are wooden boxes having two parts: upper ¼ comb is chamber and lower ¾ is brood chamber. Following types of bee boxes are used in beekeeping.

Sr. No.	Box type	Dimensions	Remark
1.	Ghos box	36 cm x 21.5 cm	These two types of bee hives are more popular in India. In India Newton's beehive are manufactured based on Bureau of Indian Standards (BIS) specifications and called as BIS hives.
2.	Newton box (BIS hive)	20.2 cm x 14.0 cm	
3.	Langstroth hive (American hive)	42.2 cm x 31.1 cm	Some other familiar bee boxes. Nowadays these boxes are widely used in commercial beekeeping. Langstroth hive is suited to *A. mellifera*.
4.	Pant, Kanje and Jeolikote No.l	42.2 cm x 12.3 cm	
5.	Dadant box (Russian hive)	47 cm x 28.6 cm	
6.	Thompson box	30.5 cm x 15.2 cm	

Hive parameters	BIS hive C type for *A. mellifera* (Modified Langstroth type)	BIS hive A & B type for *A. cerana* (Modified Newton and Jeolikote types)
Frames	Contains 10 frames	May contain 4, 8 or 10 frames
Super Chamber	Generally full super chamber is used.	Half (shallow) super chamber is generally used.
Brood/super frame size	Outside: 448x232mm Inside : 428x192mm	**Type A: Modified Newton Type** Outside: 230x165mm Inside : 210x145mm **Type B: Modified Jeolikote Type** Outside : 300x195mm Inside : 280x175mm
Bee space	10 mm	**Type A :** 7 to 9 mm **Type B :** 8 or 9 mm

II.	**Equipment used in commercial beekeeping:** A movable frame hive is composed of the following parts/appliances
1.	**Bee hive:** • It is movable wooden hive for bees with an entrance and parallel movable frames on which bees raise their combs. • It provides protection to the colony from adverse effects of external environment. The important parts of the hive are bottom/floor board with alighting board, entrance, lower/brood chamber, frames, dummy board, super/honey chamber, inner cover (crown board) and top cover.
2.	**Nucleus hive:** • Small bee hive for keeping 4-6 frames. These are used for mating of queens and division of colonies.
3.	**Observation hive:** • Small hive with glass sides to observe movements and behaviour of bees.
4.	**Synthetic combs:** • It is made up of high density polythene (plastic). It can be used in both super and brood chambers. • Since the comb is fully moulded, bees only put wax caps on the cells. • **Advantages of synthetic combs *viz.*,** More honey can be extracted, Combs can be easily sterilized, Resist wax moth attack, Combs will not be damaged during honey extraction.
5.	**Hive stand:** • This is used to keep the bee hive above the ground so as to protect the colony from termites, ants and other crawling insects and also prevent soil moisture getting into the hive or facilitate ventilation from below the hive. • The stand is made of wood or iron tubing or angle iron. • Any four legged stand of 15-25 cm high is sufficient. • Ant wells of 15 cm in diameter kept under four legs to prevent ants and other crawling insects entering into the hive.
6.	**Bottom board:** • It forms the floor of the hive made up of a single piece of wood or two pieces of wood joined together. • Wooden beading are fixed on to the lateral sides and back side.

	• There is a removable entrance rod in the front side with two entrance slits to alter the size of the hive entrance based on need. • The board is extended by10 cm in front of the hive body which provides a landing platform for bees. Size of alighting board is 40x28 cm (BIS hive).
7.	**Brood chamber:** • It is a four sided rectangular wooden box without a top and bottom. • It is kept on the floor board. • A rabbet is cut in the front and back walls of the brood chamber. • The brood frames rest on the rabbet walls. • In brood frames, bees develop comb to rear brood. • Size of brood frame is (outer dimensions) 29 x 29 x 17 cm. • There will be 8 frames. Length and height of frame is 20.5 x 14.0 cm (BIS hive).
8.	**Super chamber:** • It is kept over the brood chamber and its construction is similar to that of brood chamber. Super frames are hung inside. • The length and width of this chamber is similar to that of brood chamber. • The height may also be similar if it is full depth super as in Langstroth hive. But the height will be only half if it in a shallow super as in Newton's hive. • Surplus honey is stored in super chamber.
9.	**Hive cover/Top cover:** • It insulates the interior of the hive. • In Newton's hive it has sloping planks on either side. • On the inner ceiling plank there is a square ventilation hole fitted with wire gauze. • Two holes present in the front and rear also help in air circulation. • In Langstroth hive and BIS hive, the hive cover consists of a crown board or inner cover and an outer cover.
10.	**Inner cover:** • The inner cover is provided with a central ventilation hole covered with wire gauze help in air circulation. • The outer cover is covered over with a metallic sheet to make it water proof to rain water.
11.	**Hive Frames:** • The frames are so constructed that a series of them may be placed in a vertical position in the brood chamber or the super chamber so as to leave space in between them for bees to move. • Each frame consists of a top bar, two side bars and a bottom bar nailed together. • Both the ends of the top-bar protrude so that the frame can rest on the rabbet.
12.	**Dummy or Division Board/ Movable wall:** • It is a wooden board slightly larger than the brood frame. • It is placed inside the brood chamber. It prevents the bees from going beyond it. • It can be used as a movable wall there by limiting the volume of brood chamber which will help the bees to maintain the hive temperature and to protect them from enemies. It is useful in managing small colonies.
13.	**Bee Feeder:** • Used for providing sugar syrup as feed to the bees during dearth period. • A normal method of providing feeding is to keep a can with small holes punched on its lid. The can is filled with sugar syrup and kept over the frames in an inverted position.
14.	**Queen excluder:** • It is made up of perforated zinc sheet. • The slots are large enough to allow the workers to pass through but too narrow for the queen. A wire grid/dividing grid with parallel wire mounts can also be used as a queen excluder. It is inserted in between the brood frames and super chamber.

15.	**Queen gate:** • It is a piece of queen excluder sheet and fitted on the slot of entrance gate. • The holes in the sheet are large enough to allow free movement of worker bees in and out of the hive, but too small to allow queen's passage. • It confines the queen inside the hive. It is useful to prevent swarming and absconding. It also prevents the entry of bee enemies like wasps into the hive.
16.	**Queen cage:** • This is used for transport of queen either with a few attendant worker bees, in packages. • It is a cage made up of wood or wire gauge or plastic structure. This is useful for queen introduction.
17.	**Queen cell protector:** • It is a cone shaped structure made of a piece of wire wound spirally. It fits around a queen cell. • It is used to protect the queen cell, given from a queen right to queen fewer colonies until its acceptance by bees.
18.	**Swarm trap:** • It is a rectangular box used to trap and carry the swarm. • It is fixed near the hive entrance with one or two combs inside during the swarming season. • This box traps and retains the queen only. But the swarm coming out from the hive reenters the hive and settles on the comb, since the queen is trapped.
19.	**Drone excluder or drone trap:** • It is a rectangular box with one side open. The other side is fitted with queen excluder sheet. • At the bottom of the box there is a space for movement of worker bees. There are two hollow cones at the bottom wall of the box. • Drones entering through the cones into the box get trapped. • The narrow end of the cone is wide enough to let the bees pass out but not large enough to attract their attention or re-entry. This device is used at the entrance to reduce the drone population inside the hive.
20.	**Pollen trap:** • Pollen trapping screen inside this trap scrapes pellets from the legs of the returning foragers. It is set at the hive entrance. • The collected pollen pellets fall into a drawer type of receiving tray.
21.	**Hive tool:** • It is a piece of flattened iron with flattened down edge at one end. • It is useful to separate hive parts and frames glued together with propolis. • It is also useful in scrapping excess propolis or wax and superfluous combs or wax from various parts of the hive.
22.	**Protective dress:** **(a) Bee veil:** It is worn over the face for protection against stings. It is particularly useful for a beginner, for protecting face from bee stings during the handling of bees. **(b) Gloves:** These are used while inspecting and handling colonies to protect hands and arms. Soft leather gloves with canvas gauntlets to the elbow are the best for use. **(c) Boots:** A pair of gum boots will protect the ankles and prevent bees from climbing up under trousers. **(d) Overalls:** White overalls are occasionally worn. Light colored cotton materials are preferable since they are cooler and create less risk for antagonizing bees.

23.	**Bee brush:** • A soft-camel-hair brush is used to brush the bees off the honeycomb before it is taken for extraction.
24.	**Smoker:** • The smoker is used to calm bees and drive away bees from super. • It consists of a metal fire pot with a funnel shaped cover and a bellow. • A smoke releasing fuel (dried cow dung, hessian, waste jute bags or cardboard, old rag, wood shaving etc.) is burnt in the fire pot. • Air is injected into the pot by operating the bellow and the smoke is directed to the desired spot.
25.	**Decapping knife/ uncapping knife:** • Single or double edged steel knife is used for removing wax capping from the honey comb before putting it in the honey extractor.
26.	**Honey extractor:** • It is invented by Frang von Hruschkain 1885 • It consists of a cylindrical drum. • A rack is fixed inside the drum to hold the supper frames. • The rack is rotated by a set of gear wheels. • The decapped honey frames are kept in the slots of the rack. The rack is rotated by operating the handle. Honey flow out from the combs by centrifugal force. The excreted honey comes out through the spout present at the bottom of the container. • The honey comb is not damaged. So, it can be reused.
27.	**Travelling screen/net:** • It is a wooden frame with wire screen. It is highly useful for migration of honey bee colonies during hot summer season.
28.	**Comb foundation mill:** • This is a machine to prepare comb foundation sheet used in beekeeping to make-bees build regular combs in frames that are convenient to handle. • J. Mehring of Germany made the first comb foundation in 1857 • Comb foundation is made by passing plain sheets of beeswax between two rollers that have the regular 3-faced cell base pattern embossed on them. • The patterns on the two rollers interlock properly, so that the 3-faced cell base on one roller matches with the base of each of the three cells on the other roller. • The distance between the rollers is fixed in such a way that a thin foundation is made that is readily accepted by the bees. • The rollers rotate on opposite sides. • The rotation is done by a handle attached to the lower roller. The cell size in the cell base pattern varies according to the size of the brood cells.
29.	**Comb foundation sheet:** • It is a thin sheet of bee wax embossed with a pattern of hexagons of size equal to the base of the natural brood cells on both sides. • The size of the hexagon varies with bee species. For ***A. mellifera*** there are **19 cells** and for ***A. cerana*** **22- 23 cells/100 mm** linear length.
30.	**Embedder:** • It is a small tool with a spur or round wheel on the top. It is used to fix the comb foundation sheet on the wires of the frame. • Electric wire is also used for this purpose which is useful to reinforce the comb and give extra strength to the comb.

31.	**Miscellaneous:** • Apart from these equipment, there are several miscellaneous equipment which are required from time to time such as propolis screen, venom extractor, drip tray, swarm basket, wax melter, queen bee rearing equipment, comb foundation making equipment, honey straining, storage and processing equipment, etc.

Organizing exposure visit to research/training institutes of honey bee:

Exposure visit is useful to gain the knowledge and experience of the work culture and provides an agro-industrial exposure to the students for developing their career in the Agro based industries. It is a method by which a group gets together for the purpose of seeing an improved performance or result of practice in actual situations. This requires the group to move out of the area for a considerable period with a pre-decided programme. A field visit will be organized and the students will record their observations.

1. Place of visit:
2. Purpose of visit:
3. Which are the important equipments that you have observed during visit?
4. Which problems of research/training institutes are identified in the field visit?
5. What interesting information is noted during visit?

Answer the following questions:

1. Which are different hives are present in India?
2. What is the purpose of 10 cm meter extension board in the floor board?
3. Why should iron stands be chosen for placing the hives?
4. Where will the top cover be placed? What will happen if it is not?
5. What will happen if queen excluder is not used in the hive?
6. When and how is the drone trap used in bee keeping?
7. Why should the extractor used for honey extraction?
8. Differentiate: (a) Brood chamber Vs super chamber (b) Drone trap and swarm trap
9. Give an account of various bee keeping equipments and accessories used in apiculture.
10. Give the comments about exposure visit to research/training institutes.

*****

EXERCISE NO. 3
SEASONAL MANAGEMENT AND MIGRATION OF HONEY BEES

Date:

Objectives:

1. To study the division and uniting of honey bee boxes.
2. To study the seasonal management of honey bee for commercial beekeeping.
3. To acquaint the knowledge in context to the migratory beekeeping.

[A] Division and uniting of honey bee boxes:

I. Division of honey bee boxes:

Colony division is a method of multiplying bee colonies, *i.e.* producing two or more colonies from a mother colony. Colony division is used to control swarming, as well as in commercial beekeeping to increase the number of colonies.

Methods for colony division

(i) Natural division using queen cells developed during swarming

The presence of multiple queen cells in a colony during the swarming season indicates a need for division. Dividing such colonies and using the queen cells in new daughter colonies can help control swarming. However, although it solves the immediate problem of swarming it does not help improve the genetic traits

(ii) Colony division from queen production

Select the best colony based on the selection criteria given above. Produce queens from this colony before the onset of honey flow. These queens can be used to replace the old queen and to start new daughter colonies. The mother colony can be multiplied into several nucleus colonies but each should have at least 2 brood combs and 3–4 combs with food (nectar and pollen). The prepared colonies can then be sold or migrated according to need.

II. Uniting of honey bee boxes:

Uniting two colonies into one is done when one of them is weak or queen less or for other reason like bad traits etc. Each colony has its own colony specific odours and it is very difficult to combine the two colonies unless their odour is mixed well. Any attempt to unite these colonies without mixing their odour result in infighting and deaths will occur on large scale. Therefore, first step will involve bringing the two colonies into contact with each other. If uniting is done abruptly, the field workers of the colony shifted will not recognize the new place and returning to their original place will persist. This problem can be overcome by moving a hive gradually at the rate of two or three feet per day, so that the field bees get accustomed to the changing position of their hive and will not drift back to the old site. When colonies are sufficiently close, one or two feet apart, they are ready for uniting. They can be united by two methods either (1) Direct uniting (2) Newspaper method (3) Smoking method.

(i) Direct uniting:

The two hives to be united are brought near gradually and kept side by side. The queen with undesirable traits in one of the hives is removed. Next morning, when the bees are busy, the frames of two hives are gently put in one. The success of this method depends upon the skill with which it is done.

(ii) Newspaper method:

Top cover is removed and the frames are covered with a piece of newspaper having a few holes made with a small nail the bottom, board of the upper colony is then removed and the brood chamber, is placed above the other colony, the newspaper forming a partition between the two. After a day or two, the odours of the colonies will mix and the bees will cut through the paper and will unite together, forming a single colony. After a few days all the frames can be placed in one hive and the upper chamber can be removed.

(iii) Smoking method:

Colonies can be united using smoke method. When the colonies to be united have been brought close to each other, both should be smoked heavily and thin sugary syrup scented with oil of peppermint or wheat flour sprinkled over them. The combs with the bees of the colony to be united should be altered with the combs of the other colony. More smoke and syrup or flour should be applied and the colony closed. The work of the queen may be checked up after three or four days. It is better to unite a laying worker colony to several strong colonies by giving from one to two frames to each of them. If all its frames are united to one colony there is danger of latter's queen being killed by the laying workers.

[B] Seasonal management of honey bee boxes:

Pollens and nectar are available only during certain period. When surplus food source is available is known as "honey flow season". In contrast during dearth period there will be scarcity of food. Suitable season for starting beekeeping coincides with mild climatic conditions and availability of bee flora in plenty. Normally, spring (February-April) and post-monsoon (Sep.-Nov.) seasons are the best periods to start beekeeping. Various operations required to be undertaken for augmenting colonies productivity are given below:

I. SPRING MANAGEMENT

Management operations to be undertaken during spring are given below:

1. Examination of colonies

a) On some warm and sunny day, examine the colonies quickly and carefully with least exposure to the chilling weather and robber bees.
b) Unpack the colonies, clean the bottom board and replace the worn out hive parts.
c) Assess the colony condition, working of the queen bee, brood rearing and food reserves.
d) Provide early season stimulative sugar feeding (sugar: water =1:2), pollen or pollen substitute feeding to increase the foraging and brood rearing activity.

2. Equalizing the colonies

The colonies can be equalized by:

a) Substituting the combs with food reserves/supplementary feeding.
b) Providing the emerging bee combs.
c) Uniting the bee combs/colonies.
d) Giving young bees to the weaker colonies.

3. Provision of space

During spring, the colonies enhance the brood rearing. Hence, there should be no dearth of space to cope up with increased egg laying by the queen bee.

a) Add good quality drawn combs (with worker cells) or frames with good quality comb foundations to the brood chamber as and when required.
b) Avoid adding raised combs with too many drone cells.
c) While providing super chamber, lure the bees to the super chamber with some bait in the form of a brood/honey comb.

4. **Swarm prevention and control**

a) Examine the colonies and remove congestion. Provide more drawn combs/comb foundations, supers, etc.

b) Improve ventilation and provide required shade.

c) Clip the wings of the laying queen.

d) Use wire entrance guard/queen excluder at the bottom board.

e) Reversing brood and honey chambers for mitigating congestion in brood chamber.

f) Destruction of the queen cells raised due to swarming instinct,

g) Dividing over-crowded colonies.

5. **Control of mites and brood diseases**

Examine the symptoms of various mites and brood diseases. On spotting any, take appropriate management measures to contain the menace.

6. **Colony multiplication and commercial queen rearing**

March-April is the best season for colony multiplication and commercial queen rearing. Improve the existing stock by selective breeding of best performing colonies. Mass reared queen bee can also be used for multiplication of existing stock and also for replacement of older queen bees (re-queening).

7. **Extraction of spring season honey**

Multiple extractions of honey during this period are possible. Only ripe honey from broodless combs from super chamber should be extracted.

II. SUMMER MANAGEMENT

Mid April to June months are extremely hot. However, this is the major honey flow period too. The following operations need to be considered during the season.

1. **Shifting the colonies to thick shade**

Colonies should be moved to shady places every day by less than three feet.

2. **Regulating the microclimate of the colonies**

By using wet gunny bags over the colonies and sprinkling water around the colonies in the apiary during noon hours, temperature in the apiary can be reduced and humidity increased in hot and dry months of May and June.

3. **Provision of ventilation**

Improve the ventilation of the colonies to cope up with the respiration of the bees and hastening the honey ripening by:

a) Widening the entrance of the colony.

b) Providing additional entrance in multi-chambered colonies.

c) Staggering the chambers.

d) Placing thin wooden splinters between two adjacent chambers for the circulation of fresh air.

4. **Provision of fresh water**

a) Running water channel in the field.

b) Cemented water reservoir tanks near the tube wells/pump sets with a sufficient number of sticks or wood pieces in the tank for the bees to sit on and lap the water.

c) Earthen water bowls underneath the legs of hive stand also fulfill the water requirement of the colonies.

d) An earthen pitcher with a small hole at its bottom is placed on a tripod and a slanting wooden plank is kept below the hole of the pitcher.

5. Honey extraction

Summer season (Egyptian clover and sunflower) honey can be extracted.

III. MONSOON MANAGEMENT

Manage the colonies during this season as below:

a) Ensure colonies placement on upland area and away from village water ponds.
b) Clean and bury deep the debris lying on the bottom board.
c) Keep the surrounding of the colonies clean by cutting the unwanted vegetation which may hamper circulation of air.
d) Provide sugar feeding (sugar: water=l:l), if required.
e) Check robbing within the apiary.
f) Unite weak/laying worker colonies. Control wax moth, ants, wasps and bee eating birds.

IV. AUTUMN MANAGEMENT

Important operations to be undertaken during this season, are:

a) Provision of space.
b) Strengthening the colonies to stimulate drone brood rearing, if queen bee rearing is to be undertaken.
c) Control of ectoparasitic mites, brood diseases, wax moths and wasps.
d) Autumn honey extraction before the winter sets in.

V. WINTER MANAGEMENT

Normally winter extends from December to mid February but this period may vary from region to region. During winter, very low temperature, westerly chilly winds, foggy/cloudy days and winter hamper the bee activity. *Brassica* comes in bloom during January. To perpetuate the colonies through winter, following operations are generally required:

1. Colony examination

Examine the colonies on a warm, sunny day for the presence of queen, brood and food reserves. Open the colony for minimum time to avoid chilling of brood. Weak colonies should be united with stronger ones so that the strong unit over-winters well.

2. Feeding

If there is food scarcity or expected in the ensuing winter, feed concentrated (sugar : water = 1:1) sugar syrup (supplementary feeding) by filling in the drawn combs at the onset of severe winter.

3. Shifting colonies to sunny places

The colonies should be shifted to sunny places with hive entrances facing south-eastwards.

4. Protection from the chilly winds

Plug cracks and crevices and narrow down the hive entrance.

5. Unite weak colonies with stronger ones

Follow newspaper method for uniting the colonies.

6. Removal of extra drawn combs and winter packing

Remove the extra empty combs and store them properly to save them from mice/rats. Depending upon the strength of the colonies and severity of winter, provide one or two-sided inner winter packing combined with need based outer packing.

[C] Migratory beekeeping

While preparing the honey bee colonies for migration, a number of points needed to be considered are given below:

1. Season

a) Fasten the various hive parts and move the colonies during late evening, night or early morning, when all the bees are inside the hive, after closing the hive entrances with wire screen, ensuring required ventilation.

b) In cold and rainy weather, the hives should be covered with a tarpaulin when being moved. Exposure to cold has the effect of causing bees to consume stores heavily to produce more heat and cluster together on the nest as they do in winter.

c) During summer or monsoon season, colonies should be migrated during night when it is cooler and in hives with enough ventilation by exchanging the inner cover with traveling-screen.

2. Distance of migration site

a) Very long distance migrations of apiaries during winter at a stretch are possible provided the bees have sufficient food reserves and required ventilation. During cold weather, bees consume excessive food stores to produce heat and cluster together over the brood.

b) The hive body and supers should be nailed or fixed properly to avoid their slipping *enroute*.

c) During summer, it is better to have one or two halts/ journey breaks for short temporary siting of the apiary for a day or two at some suitable place having some bee flora for easing out the confined bees. Moving the colonies continually for more than 48 h often leads to their brood mortality.

3. Number of hives

If the number of colonies is small, it will not be economical to migrate them as the carriage/ transport charges per colony will be much higher than when the beekeeper has full vehicle load. However, in such cases, make it a full truck load by joining with fellow beekeepers who also intend to take up migration to the same or nearby areas.

4. Colony strength

Bees are killed very often by overheating and lack of aeration but seldom by getting too cold. If weather is very hot and the colony is populous and hive is not spacious enough to allow expansion of the cluster, bees may very quickly smother/ get suffocated even when the top of the hive is covered with full wired travelling-screen. Thus, alternatively, the populous colonies may be divided and empty combs may be added for the expansion of the cluster in the hives before migration.

5. Preparation and packing of the colonies for migration

a) Extract the surplus honey, if any, a few days prior to migration.

b) All cracks and crevices in the hive should be sealed to bee-tightness.

c) Excessively broken hive parts should be replaced with new ones.

d) The hive body, bottom board and inner cover should be fastened together by stapling/ nailing.

e) Always use two nails in slanting position on each side of every juncture. An alternative to the nails is to use metal or nylon travelling belts (migration belts) around the hive.

6. Type of the vehicle, and loading and unloading the colonies

a) While migrating the colonies in vehicles such as trucks, the jerking movements will be forward and backward, hence, the length side of the hives should be kept parallel to the length of the vehicle.

b) While loading the colonies in a tractor-trailer where the jerking movements are sideways, the bee hives (colonies) should be loaded with their length side parallel to the breadth of the vehicle or the axle of the vehicle.

7. **Time of the day**

If the whole of the apiary is to be shifted, it is better to move the bees in the evening or at night (when all the bees are inside the hive and temperature is low) or during inclement or cold weather when the bees are not foraging.

8. **Timing in relation to flowering of crops**

Colonies should not be taken to crop needing pollination until it is flowering sufficiently to be the predominant species in the locality. The delay in shifting colonies to the crop until flowering has begun, always increases pollination, particularly when the crop has short flowering period and is less attractive to bees than the other crops in the area. The same is true for honey production.

9. **Placement of the migrated stock**

a) The migrated honey bee colonies should be sited away from the passages/ walkways where human or domestic animals' movements are expected.

b) If migration is for pollination purpose, the bee colonies be placed within the crop and should be evenly distributed in the area to harvest the maximum pollination benefits and should not be crowded at one place.

Answer the following questions:

1. Give in brief about method of honey bee colony division.
2. Which are the important methods of uniting of honey bee boxes?
3. Mention the precaution to be taken during spring and summer month.
4. Why weak bee colonies are united into stronger ones?
5. Why bee boxes are migrated during night time?
6. Give the precaution to be taken during migratory beekeeping.

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EXERCISE NO. 4

HONEY BEE PASTURAGE, FORAGING AND COMMUNICATION

Date:

Objectives:

1. To study the bee pasturage and floral diversity to the honey bees.
2. To acquaint the knowledge of foraging attributes and communication in honey bees.

Honey bees gather nectar and pollen from plants as their food. Honey bees collect nectar and pollen from flowering plants. Nectar is a sweet secretion from the floral and extra-floral nectaries of flowers and is the raw material for honey. Pollen is protein-rich food for the bees. As nectar and pollen are basic raw materials for beekeeping, a thorough knowledge of the bee flora of a locality is essential. Efficient beekeeping means managing honey bee colonies in such a way to obtain maximum colony population to coincide with the major honey flow in an area and to utilize the honey production and pollination.

I. Foraging attributes of honey bees:

The field bees get activated in the morning and go out on foraging and collect pollen, nectar, propolis and water, carry them to the hive and make a number of trips till sunset. The bees that go out first to find out new sources of these materials are called *searcher bees* or *scout bees*. They return to the hive and communicate the message to young foraging bees by means of definite patterns of dancing. At any time bees collect most of the materials from a single or a few plant species but bees in two different colonies located side by side may visit entirely different sources, mainly due to the differences in discoveries by the scout bees.

Duties of forager bees

Collect i) pollen, ii) nectar, iii) water, iv) propolis v) juice of damaged fruits (when bloom is scarce)

Utility of bee flora to honey bees:

In general, a honey bee depends on a wide variety of plants for nectar and pollen. These include several species of wild and cultivated plants. For commercial beekeeping, large crop acreage with good floral qualities is required. A beekeeper must have the details about the availability and suitability of bee flora. Following are the qualities of good bee flora:

- Long flowering period
- High density of flowers per unit of the plants
- Good quality of nectar with high concentration of sugars
- Easy accessibility of the nectaries to the honey bees and ease in collection of nectar
- Availability of flora in the close vicinity of the apiary

LIST OF IMPORTANT BEE FLORA IN INDIA

S. No.	Scientific Name	Common Name	Family	Flowering period	Source type
		Field crops			
1	*Eleusine coracana*	Ragi	Poaceae	3-4	P_2
2	*Oryza sativa*	Rice	Poaceae	9-10	P_1
3	*Pennisetum tyhhoides*	Bajra	Poaceae	11-10	P_2
4	*Sorghum bicolor*	Jowar	Poaceae	9-10	P_2
5	*Zea mays*	Maize	Poaceae	1-12	P_3

Legume Crops					
6	*Ca1us ca1*	Red gram	Fabaceae	8-11	N_3P_2
7	*Cicer arietinum*	Bengal gram	Fabaceae	12	N_2P_2
8	*Dolichos biflorus*	Horse gram	Fabaceae	10	N_1P_1
9	*Medicago sativa*	Lucerne	Fabaceae	3-4	N_2P_2
10	*Phaseolus mungo*	Black gram	Fabaceae	8 - 10	N_1
11	*Phaseolus radiatus*	Green gram	Fabaceae	8	N_1P_1
12	*Sesbania graniflora*	Dhiancha	Fabaceae	6- 7	P_1
13	*Vigna unguiculata*	Cowpea	Fabaceae	8	N_1P_1
Oilseed Crops					
14	*Arachis hypogea*	Groundnut	Fabaceae	8-9	N_2P_2
15	*Brassica napus*	Rapeseed	Brassicaceae	12-3	N_1P_1
16	*Carthamus tinctorius*	Safflower	Asteraceae	12-1	N_3P_2
17	*Eruca sativa*	Taramira, Rocket	Brassicaceae	12-8	N_2P_2
18	*Guizotia abyssinica*	Niger	Asteraceae	4-5	N_1 P_3
19	*Helianthus annuus*	Sunflower, Surajmukhi	Asteraceae	1-12	N1P3
20	*Ricinus communis*	Castor	Euphorbiaceae	8-9	N_1P_1
Fiber Crops					
21	*Corchrus olitorius*	Jute	Malvaceae	3-4	N_2P_2
22	*Gossypium arborium*	Cotton	Malvaceae	4-1	N_1P_1
Vegetable crops					
23	*Abelmoschus esculentus*	Lady's finger	Malvaceae	1-12	N_3P_2
24	*Allium cepa*	Onion	Liliaceae	5-7	N_3P_3
25	*Amaranthus viridis*	Amaranthus	Amaranthaceae	1-12	N_1
26	*Brassica oleracea. capitata*	Cabbage	Brassicaceae	2-4	N_3P_2
27	*Brassica oleracea botrytis*	Cauliflower	Brassicaceae	2-4	N_3P_2
28	*Capsicum chinense*	Capsicum	Solanaceae	11-2	N_3P_1
29	*Coccinia indica*	Little gourd	Cucurbitaceae	1-8	N_3P_2
30	*Coriandrum sativum*	Coriander	Apiaceae	2-3	N_1P_1
31	*Cucumis melo*	Muskmelon	Cucurbitaceae	3-4	N_3P_2
32	*Cucumis sativus*	Cucumber	Cucurbitaceae	10-11	N_3P_2
33	*Cucurbita maxima*	Squash gourd	Cucurbitaceae	2-3	N_3P_1
34	*Daucus carota*	Carrot	Apiaceae	3-4	N_2P_2
35	*Dolichos lablab*	Field bean	Fabaceae	9	N2P1
36	*Glycine max*	Soybean	Fabaceae	8-9	N1P2
37	*Ipomea batatus*	Sweet potato	Convolvulaceae	10-12	N_1P_1
38	*Lagenaria vulgaris*	Pumpkin	Cucurbitaceae	3-9	P_1
39	*Laginaria siceraria*	Bottle gourd	Cucurbitaceae	1-12	N_3P_2
40	*Luffa acutangula*	Ridge gourd	Cucurbitaceae	11-2	N_3P_1
41	*Lycopersicon esculentum*	Tomato	Solanaceae	1-12	P_1
42	*Momordica charantia*	Bitter gourd	Cucurbitaceae	4-7	N_2P_2
43	*Moringa oleifera*	Drumstick	Moringaceae	12-4	N_1P_1
44	*Phaseolus vulgaris*	French bean	Fabaceae	1-12	N_1P_1
45	*Raphanus sativus*	Radish	Brassicaceae	2-4	N_3P_1
46	*Solanum melongena*	Brinjal	Solanaceae	1-12	P_1
47	*Solanum tuberosum*	Potato	Solanaceae	12-2	P_1
48	*Trigonella foenumgracum*	Methi	Fabaceae	1 -12	N_1

Plantation Crops					
49	*Cocos nucifera*	Coconut	Arecaceae	1 -12	P_3
50	*Nicotiana tabaccum*	Tobacco	Solanaceae	12-1	P_1
Fruit Crops					
51	*Anacardium occidentale*	Cashewnut	Anacardiaceae	12-2 9-10	N_2P_1
52	*Annona squamosa*	Custard apple	Annonoceae	4- 6	N_1P_2
53	*Areca catechu*	Arecanut	Arecaceae	1 -12	P_3
54	*Artocarpus integrifolia*	Jack fruit	Moraceae	12-3	P_1
55	*Carica papaya*	Papaya	Caricaceae	7-9	N_3P_2
56	*Citrus spp.*	Citrus	Rutaceae	2-3	N_1P_1
57	*Malus domestica*	Apple	Rosaceae	3-4	NP
58	*Mangifera indica*	Mango	Anacardiaceae	12-3	N_1P_1
59	*Manilkera achras*	Sapota	Sapotaceae	10-3	N1
60	*Musa paradisiaca*	Banana	Musaceae	1 -12	N_1P_1
61	*Prunus armeniaca*	Apricot	Rosaceae	3-4	N_1P_1
62	*Psidium guajava*	Guava	Myrtaceae	2-4	N_3P_3
63	*Punica granatum*	Pomegranate	Punicaceae	4-7	N_1P2
64	*Pyrus communis*	Pear	Rosaceae	2-8	N_2P_2
65	*Syzigium jambos*	Rose apple	Myrtaceae	12- 4	N_3P_2
66	*Vitis vinifera*	Grape	Vitaceae	9-12	N_2P_1
Ornamental Plants					
67	*Aster thomsoni*	Aster	Asteraceae	8 - 10	N_1P_1
68	*Callistemon lanceolus*	Bottle brush	Myrtaceae	5-7	N_3
69	*Delonix regia*	Gulmohar	Fabaceae	3-5	N_1P_1
70	*Gerbera launiosa*	Gerbera	Agavaceae	1-12	N_1P_2
71	*Lagerstromia indica*	Pride of India	Lythraceae	2-4	P_1
72	*Rosa indica*	Rose	Rosaceae	6-7	N_3P_3
73	*Tagetes minuta*	marigold	Asteraceae	1-12	N_2P_2
74	*Thevetia peruviana*	Kanagila	Apocynaceae	1-12	NP
Medicinal and Aromatic plants					
75	*Ammi mages*	Honey plant	Apiaceae	3-4	N_3P_3
76	*Foeniculum vulgare*	Fennel	Apiaceae	4-5	N_3P_3
77	*Lathyrus sativus*	Khesari	Euphorbiaceae	3-4	N_1P_2
78	*Trachyspermum ammi*	Ajwain	Apiaceae	3-7	N_2P_2
Weeds					
79	*Abelmoschus ficulneus*	Van Bhindi	*Malvaceae*	8-9	N_3 P_2
80	*Dhatura fistula*	Dhatura	Salanaceae	1-12	N_3 P_2
81	*Lantana camera*	Lantana	Verbenaceae	1-12	N_1
Trees					
82	*Acacia arabica*	Babul	Mimosaceae	7-11	N_1P_1
83	*Acacia catechu*	Khair	Mimosaceae	7-9	P_1
84	*Acacia modesta*	Acacia	Mimosaceae	5-7	N
85	*Actinodaphn ancustifolia*	Pisa	Lauraceae	10-3	N_1
86	*Albizia lebbeck*	Siris tree	Mimosaceae	2-4	N_1P_1
87	*Azadirachta indica*	Neem	Meliaceae	3-4	N_2
88	*Bauhinia purpurea*	Khairwal	Fabaceae	2-8	N_1P_1
89	*Bombax ceiba*	Simal	Malvaceae	1-3	N_1P_2

90	*Callistemon lanceolatus*	Bottle brush	Myrtaceae	1-12	N_3P_1
91	*Gliricidia septium*	Gliricidia	Caesalpinaceae	2-4	N_1P_1
92	*Grewia spp.*	Phalsa	Teliaceae	7-11	N_2P_1
93	*Jacaranda acutifolia*	Jacaranda	Bignoniaceae	2- 4	N_1P_1
94	*Manihot glagiovii*	Rubber Tree	Euphorbiaceae	7-8	N_3
95	*Morus alba*	Mulberry	Moraceae	2-6	P_1
96	*Phyllanthus emblica*	Amla	Euphorbiaceae	2-4	N_1P_1
97	*Tamarindus indica*	Tamarind	Caesalpinaceae	5-6	N_1 P_1
98	*Zizyphus jujuba*	Wild Ber	Rhamnaceae	5-6	N_3 P_2
99	*Ziziphus mauritiana*	Ber	Rhamnaceae	3-5	N_1 P_1

N : Source of nectar **Flowering Period (Month):-** January to December (1-12)
P:Source of pollen **Source:-1:** Major; **2:**Medium; **3:** Minor

II. Communication in honey bees

Bees communicate using various pheromones, including the queen's substance, vasanov gland secretion, alarm pheromone emitted from sting and secretion of tarsal gland. In addition to that the bees also communicate by performing certain dances. When scout bees return to the box after foraging they communicate to the other forages present in the box about the direction and distance of the food source from the hive by performing dances.

The important types of dances are noticed.

1. **Round dance:** It is used to indicate a short distance (Less than 50m in case of *A. mellifera*). The bee runs in circles, first in one direction and then in opposite direction, (clockwise and anticlockwise).
2. **Tail wagging dance or Wag -tail dance:** This is used to indicate long distance (more than 50m in case of *A. mellifera*). Here the bee makes two half circles in opposite directions with a straight run in between. During the straight run, the bee shakes (wags) its abdomen from side to side, the number of wags per unit time inversely proportional to the distance of the food (more the wags, less the distance.). The direction of food source is conveyed by the angle that the dancing bee makes between its straight run and top of the hive which is the same as between the direction of the food and direction of the sun. The bees, can know the position of the sun even if it is cloudy.

Answer the following questions:

1. Give in brief about **foraging attributes of honey bees.**
2. Differentiate: Bee flora Vs Dearth period
3. Differentiate: Major honey flow period Vs Minor honey flow period
4. What you understood by floral fidelity?
5. Mention the duties of forager bees
6. Enlist the important bee flora in waghai with type of source to the honey bee.
7. Observe the honey bee fauna in waghai and note down important morphological characteristics of each species.
8. Differentiate: Round dance Vs Tail wagging dance

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EXERCISE NO. 5

PESTS AND DISEASES OF HONEY BEE

Date:

Objectives:

1. To study the important insect pests and non insect pests of honey bees.
2. To know the important diseases of honey bees.

Bee enemies cause great loss to honey bee colonies. These bee enemies destroy the raised combs, hives and hive parts, catch and kill bees and brood, adversely affect colony development, eat away the food reserves and cause nuisance to the bees and beekeeper, thus, reducing the colony productivity and returns per colony. Major bee enemies are wax moths, wasps, birds, ants and mites, etc.

A.	Insect and non insect pests of honey bee
1.	**Greater wax moth**: *Galleria mellonella* (Galleriidaee: Lepidoptera) Adults are brown in colour. Female moth enters the hive during night and lays creamy white eggs in groups in the cracks and crevices of the hive, combs and in the gap between super and brood chamber. Caterpillar is dirty white in colour. Egg, larval and pupal periods are 8 -10, 30 and 8 days, respectively. **Symptoms**: Comb with numerous black faecal pellets. Usually uncovered or partially covered combs (in storage) and weaker colonies are damaged. In case of severe infestation, bees may abandon the colony.
2.	**Lesser wax moth**: *Achroia grisella* (Galleriidaee: Lepidoptera) It is seen commonly at higher altitudes. The larvae feed mainly on the debris of the combs.
3.	**Wax beetle**: *Platybolium alvearum* (Tenebrionidae: Coleoptera) Adults are black colour small beetle. It is found in hives of unhygienic conditions. If feeds on the debris and on old combs in weak colonies.
4.	**Ants**: Black ant, *Camponotus compressus*: Household ant, *Dorylus labiatus Monomorium* spp. (Formicidae: Hymenoptera) Ants vary in colour, ranging from black to red. They attack weak colonies and carry away the honey, pollen and the brood, leading to destruction and end of the colony.
5.	**Wasps**: **(i) Yellow banded hornet** : ***Vespa cincta*** **(Vespidae: Hymenoptera)** It is a social insect. It is large with a broad transverse yellow band in the abdomen. It constructs a papery nest in hollow spaces. It catches bees from the alighting board or while in air. It macerates the bee for feeding its young. **(ii) Bee hunter wasp: *Palarus orientalis* (Vespidae: Hymenoptera)** It preys on approximately 20 bees / day while in air. It also stings and carries bees to underground nests
6.	**King crow: *Dicrunus macrocercus*: Bee eater: *Merops orientalis*** They capture bees and devour them. Since birds help in keeping down insect population, no large – scale measures against them can be recommended.
7.	**Lizards, toads and frogs**: Vertebrata All the three have sticky tongue, which helps them to capture bees. They remain on the alighting board and catch the bees.
8.	**Spiders** (Aranae: Arachnida) In nature, spiders spin web nearby hives. When the bees caught in the silken web. Spiders feed them.

9.	**Ectoparasitic mite, *Varroa destructor* Anderson & Trueman** In the infested colonies, adult mites can be seen on adults, larvae and pupae of honey bees. Two to six mites on an infested individual honey bee adult/ brood result in decline in colony size and activity.
10.	**Endoparasitic mite, *Acarapis woodi*** Rennie (Acarine mite / Tracheal mite) Crawling bees on the ground with disjointed wings called K-winged bees. Such bees cannot fly. Infested crawling bees try to climb on a grass blade and finally fall down.

B. Diseases of honey bee:

1. Brood disease of honey bee

Parameter	American Foul Brood	European Foul Brood	Sac Thai Brood
Causal Organism	*Bacillus larvae*	*Mellisococus pluton*	Thai Sac brood Virus
Time of death	Late larval or early pupal stage	Coiled larvae in unsealed cell and rarely late larval	Late larval stage in unsealed cell
Appearance of the capping	Cappings sunken usually have holes: many are removed	Some cappings perforated	Cappings removed or punctured
Position of the dead brood consistency	Extended on the cell base. Tooth pick stirred into decayed larva and slowly withdrawn there is ropiness	Coiled twisted or collapsed. Soft and gummy but no ropiness	Extended with head curled up, tough larval, skin with watery or granular contents, turn into sac like structure.
Brood affected	Worker, rarely drone or queen	Worker, drone and queen	Worker only
Mode of transmission	Through infested bees	Through spores along with faeces. Workers pick up the spores while cleaning.	From adult to larva, through trophallaxis, swarms, exchange of brood combs.

2. Adult disease of honey bee

Particular	Nosema	Amoebic	Acarine / Isle of Wight
Causal organism	*Nosema apis*	*Malphigamoeba mellificae*	*Acarapis woodi*
Site of infection	Lining of stomach	Malpighian tubules	Through trachea and feeds upon body fluids.

Mode of transmission	Spores passed out with faeces of infected bees and eaten up by bees cleaning the combs.	Cysted amoebae passed into intestine and to the exterior along with faeces	Through worker bees.
Behaviour of affected bees	Crawlers on leaf blades, sluggish, abdomen distended and dysenteric bees	Produces dysentery	Many crawlers, when mites block the trachea, bees die
Age when Affected	Older adults	Older adults	Older adults

Answer the following questions:

1. Enlist the important insect pest of honey bee with their damaging stages.
2. Differentiate: Greater wax moth Vs Lesser wax moth
3. Why ant wells are placed under the bee hive?
4. Enlist the natural enemies of honey bee.
5. Enlist the important non insect pest of honey bee.
6. Give the symptoms of following disease of honey bee
   a) American foulbrood (AFB)
   b) European foulbrood (EFB)
   c) Nosema disease
   d) Amoeba disease
   e) Sacbrood disease

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EXERCISE NO. 6

TYPES OF SILKWORM, VOLTINISM AND BIOLOGY OF SILKWORM

Date:

Objectives:

1. To study the types of silkworms.
2. To know the voltinism and biology of silkworm (Mulberry and Eri silkworm).

Sericulture:

The practice of rearing silkworms for production of silk is called **Sericulture**. Silk producing insects are commonly referred to as serigenous insects. Silkworm is a common name for the silk-producing larvae of silk moths. Silk is the secretion from the salivary glands which are found on both sides of the alimentary canal of silkworm larvae and this secretion harden into fine threads called silk. The cocoons with which pupae are covered by the worms are utilized for silk production.

I. Types of silkworms:

There are four kinds of natural silk, which are commercially known and produced. Among them, mulberry silk is the most important and contributes as much as 95% of world production. The other non-mulberry silks are eri silk, tasar silk and muga silk.

Characters	Mulberry silkworm	Eri silkworm	Tassar silkworm	Muga silkworm
Species	*Bombyx mori*	*Philosamia ricini* *P. cynthia*	*Antheraea pernyi* *A. myliltta* *A. yamamai*	*A. assama*
Family	Bombycidae	Saturniidae	Saturniidae	Saturniidae
Host plants	Mulberry	Castor	Terminalia, Dalbergia, Shorea, Zizyphus, Ficus, *etc*.	Som *Machilus bombycina*; Soalu, *Litsaea polyantha*
Cocoon	Silvery white in colour. Continuous and uniform type with high silk production.	White or brick red in colour. Neither uniform not continuous type with moderate silk production.	Brown in colour. Continuous and uniform type with high silk production.	Lustrous golden yellow in colour. Continuous and uniform type with less silk production.
Domestication feasibility in India	Easy and economical	Rare	This cannot be domesticated	Rare and confined to Assam

II.	**Voltinism in silkworm:**
1.	**Univoltine:** It refers to organisms having one brood or crop or generation per year. Their larvae are of robust size and consume much more food. These produce larger sized cocoons having 200–300 mg shell weight. Such cocoon yields 800 – 1200 m silk. They show diapause.
2.	**Bivoltine:** It refers to organisms having two broods or crop or generations per year. Their larvae are comparatively of moderate size. Shell weight of the cocoon is 150 – 200 mg. They yield 600 – 800 m silk.
3.	**Multi or Polyvoltine:** It refers to organisms having more than two broods or crop or generations per year. Their larvae are comparatively of small size. Shell weight of the cocoon is 100 – 150 mg. They yield 300 – 400 m silk.
III.	**Morphology and biology of mulberry silkworm:**
1.	**Egg:** • Eggs are laid in clusters on the under surface of mulberry leaves during night time. • A female lays about 300-400 eggs popularly called as silk-seeds measuring about 1 to 1.3 mm in length and 0.9 to 1.2 mm in breadth. • The eggs are small, ovoid, flat, ellipsoid or oval pale, white or yellow and seed like in appearance. At the time of hatching, it become black and hatch within 10-12 days during summer and 30 days during winter. In the univoltine race, the eggs do not hatch during winter and undergoes into hibernation. • One generation is completed in univoltine race/year whereas 2-7 generations completed in multivoltine race/year.
2.	**Larva:** • The newly hatched larva is white to dark in colour and measures about 3 mm in length. There are 3 pairs of thoracic and 5 pairs of abdominal legs which are situated on the 3,4,5,6 and 10^{th} abdominal segments. • On the dorsal side of the eighth abdominal segment, the larva carries the caudal horn. The larva moults 4-5 times and becomes mature in 30-35 days. • The full grown larva is creamy white in colour and measures about 75 mm in length. In the female, a pair of milky white spots is appearing on each of the eighth and ninth segments. In male, a small milky white body appears at the centre of the ventral side between the eighth and ninth segments. • Cocoons formation takes place within 25 hours.
3.	**Pupa:** • The cocoon measures about 38 mm in length and 19 mm in breadth. Oval in shape and white or yellowish in colour. • The larva pupates inside the cocoon which is made up of a single thread. • The pupa inside the cocoon is reddish-brown in colour and measures about 25 mm x 7 mm. The pupal period lasts for 10-15 days. • At the time of emergence of adult, it secretes an alkaline fluid which pierces the cocoon and adult comes out.
4.	**Adult:** • The moth of silkworm is a creamy white colour measuring about 30 mm in length and a wingspan of about 40-50 mm. The female is bigger and less active than male. The head is small and bears a pair of black compound eyes and bipectinate antennae. The mouth parts are vestigial; therefore the moth does not take food and lives only for about 2 to 3 days. • The anterior portion of thorax is narrower than the posterior. • The fore wings are provided with dirty dark coloured stripes and the body is covered with hairs.

IV.	**Morphology and biology of eri silkworm:**
1.	**Eggs:** • The colour of eggs turns dark when they are about to hatch. The little black spot can be seen on egg as it is the heads of the emerging silkworms. The incubation period is about 9.0 to 10.0 days in summer and 10 to 15 days in winter season.
2.	**Larvae:** • Larvae are covered with tiny hairs. Larvae are very imposing and looking with all those spiky knobs but they are quite soft. Total larval period lasts 25 -30 days.
3.	**Pupa:** • The cocoons are whitish in colour. It is loose type of cocoon. • Pupa is brown in colour. The pupal duration is about 15 to 18 days during summer and 35 to 40 days during winter.
4.	**Adult:** • Adult moths are large with wings spanning about 10 cm. The wings are greyish brown in colour. Adult moths emerge during morning ho urs to mid day; males emerge earlier than the females. After an hour of emergence, mating occurs and continues till evening. • Males are then separated. Both male and female have brown (chocolate), black or green coloured wings with white semi-circular markings and woolly white abdomen. The male is smaller than female and bear bushy antennae and narrow abdomen. About 400 to 500 eggs are laid by each gravid female during her lifespan. Eri silkworm completed its life cycle in 6 weeks during summer and 12 weeks during winter season.
V.	**Organizing exposure visit to research/training institutes of silkworm:**
	Exposure visit is useful to gain the knowledge and experience of the work culture and provides an agro-industrial exposure to the students for developing their career in the Agro based industries. It is a method by which a group gets together for the purpose of seeing an improved performance or result of practice in actual situations. This requires the group to move out of the area for a considerable period with a pre-decided programme. A field visit will be organized and the students will record their observations. (Place of visit, Purpose of visit, Which are the important equipments that you have observed during the visit? Which problems of research/training institutes are identified in the field visit? What interesting information is noted during visit?

Answer the following questions:

1. Enlist the important species of silkworm.
2. What you understand by non mulberry silkworm?
3. Mention the precaution to be taken during Chawki rearing.
4. Which species of silkworm are difficult to domesticate?
5. Differentiate: Univotine Vs Bi-voltine
6. Give the important morphological characteristics of pupa and cocoon of mulberry silkworm and eri silkworm.
7. Give the comments about exposure visit to research/training institutes.

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EXERCISE NO. 7

CULTIVATION OF SILKWORM FOOD PLANTS

Date:

Objectives:

1. To study the cultivation practices of mulberry host plant [Moriculture]
2. To know the cultivation practices of non-mulberry host plant (castor) [Ericulture]
3. To study the methods of harvesting and preservation of leaves of food plants.
4. To know the important pest and disease of food plants.

Components of sericulture:

Sericulture is an agro based industry comprising three main components, *viz*. cultivation of food plants of the silkworms, rearing of silkworms, and reeling and spinning of silk. The first two are agricultural and the last one is an industrial component.

I.	**Mulberry cultivation:** The cultivation of mulberry plants for silkworm rearing is called **Moriculture** as the plant belongs to the family Moraceae. Among 20 species of mulberry, the most common are *Morus alba*, *M. indica*, *M. serrata* and *M. latifolia*.
1.	**Soil and climate:** The soil should be deep fertile, well drained clayey loam. Saline and alkaline soils are not preferred. Mulberry can be grown in a rainfall ranged from 600mm to 2500mm.
2.	**Plantation season:** Irrigated crop: September-October. Rainfed crop: April-May.
3.	**Mulberry varieties:** **Irrigated:** S-30, S-36, S-41, S-54, S-1635, JL-1, C-776, TR-10, VR-9 and Kanva-2 **Semi-Irrigated:** Kanva-2 and MR-2 **Rainfed:** S-13, S-34, RFS-135, RFS-175 and S-1635
4.	**Selection of planning material:** The mulberry plants are raised from semi-hard wood cuttings with 15 - 20 cm length having 3 - 4 active buds. The cuttings are selected from well established garden of 8 - 12 months old.
5.	**Nursery:** Select red loamy soil of 800 sq. m. for raising sapling for planting one hectare of main field. Size of raise nursery beds should be of 3 m x 1.7 m size.
6.	**Pre-treatment of cuttings and planting:** Cuttings are treated with biofertilizer, *Azospirillium* @ 1 kg/40 litres of water for 30 minutes before planting for inducement of early rooting. Apply VAM @ 100 g/m^2 of nursery area. Irrigate the nursery bed. Plant the cuttings in the nursery at 15cm x 7cm spacing at an angle of 45^0.
7.	**Planting method and spacing:**

Planting method	Irrigated		Rainfed	
	Spacing (cm)	No. of cuttings/ha.	Spacing (cm)	No. of cuttings/ha.
Ridges and furrows	60 x 60	27780	90 x 90	12350
Pit systems (45 x 45 cm pit)	90 x 90	12350	90 x 90	12350

8.	**Manure and fertilizers for main field:** Apply FYM @ 20 t/ha for the irrigated crop and 10 t/ha for rainfed crop during last ploughing. Apply organic manure (FYM) 1.25 kg/pit in case of pit system is adopted. **1. Irrigated / Semi irrigated:**

Particular	Row system (Kg/ha)			Pit System (Kg/ha)		
	N	P	K	N	P	K
Recommendation	300	120	120	280	120	120

First dose	60	60	60	60	60	60
Second dose	60	-	-	40	-	-
Third dose	60	60	60	40	-	-
Fourth dose	60	-	-	60	60	60
Fifth dose	60	-	-	40	-	-
Sixth dose	-	-	-	40	-	-

2. Rainfed:

Particular	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)
Recommendation	100	50	50
First dose	50	50	50
Second dose	50	-	-

9. **Bio-fertilizers:**
Apply *Azospirillium* @ 20 kg/ha in five split doses along with phosphobacterium @ 10 kg/ha in two equal splits.

10. **Irrigation:**
(a) Ridge and furrows method: It is most efficient method of irrigation. Comparatively less amount of water is required. These furrows can be used as drainage channel during rainy season.
(b) Flatbed method: Rectangular beds can be prepared. Water runoff is relatively less. This is labour intensive method. Better crop growth can be maintained in this method.

11. **Weed management:** Grammoxone @ 2-3 lit/ha as post-emergence weedicide. Remove weeds by hand hoe.

12. **Pruning of mulberry plants:**
Pruning is the process of removing the branches of mulberry plant with the objective to give a convenient shape and size to increase the leaf yield
(a) Bottom pruning: Plants are cut at ground level leaving 10-15 cm stump above the ground once in a year.
(b) Middle pruning: Branches are cut at 40- 60 cm above the ground level. After bottom prunings, subsequent cuts are made at 45-50 cm height.
(c) Kolar or Strip system: Branches are cut at ground level every time in closely planted area. Thus, it receives five pruning every year. This type of severe pruning requires heavy fertilization and irrigation.

13. **Harvesting of mulberry leaves:**
(a) Leaf picking: Picking starts at 10 weeks after bottom pruning and subsequent pickings are done at an interval of 7-8 weeks with harvesting of individual leaves
(b) Branch cutting: Entire branches are cut and fed to the worms. Before that, toping is done to ensure uniform maturity of the lower leaves.
(c) Whole shoot harvest: Branches are cut at ground level by bottom pruning. Shoots are harvested at an interval of 10-12 weeks.
Time of harvest: It is preferable to harvest the leaves during morning hours.
Preservation of leaves: Use wet gunny bags to store the leaves or cover the bamboo basket with wet gunny bags to keep it cool and fresh.

14. **Mulberry leaves yield:** The yield of irrigated varieties are about 40 tonnes leaves/ha/year while rainfed varieties can yield about 15 to 20 tonnes leaves/ha/year with proper cultivation practices.

Major insect pests and diseases of mulberry crop:

1. Important insect pests of mulberry crop:

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
1.	Pink mealy bug	*Maconellicoccus hirstus*	Hemiptera	Pseudococcidae	Nymphs and adults
2.	Jassid/ leaf hopper	*Empoasca flavescens*	Hemiptera	Cicadellidae	Nymphs and adults
3.	Black Scale	*Saissetia nigra*	Hemiptera	Coccidae	Nymphs and adults
4.	Red Scale	*Aondiella auranti*	Hemiptera	Diaspididae	Nymphs and adults
5.	Spiralling whitefly	*Aleurodicus disperses*	Hemiptera	Aleyrodidae	Nymphs and adults
6.	Thrips	*Pseudodendrothrips mori*	Thysanoptera	Thripidae	Nymphs and adults
7.	Tobacco leaf caterpillar	*Spodoptera litura*	Lepidoptera	Noctuidae	Larvae
8.	Moringa hairy caterpillar	*Eupterote mollifera*	Lepidoptera	Eupterotidae	Larvae
9.	Tussock caterpillar	*Euproctis fraterna*	Lepidoptera	Erebidae	Larvae
10.	Brown hairy caterpillar / Tussock moth	*Porthesia scintillans*	Lepidoptera	Lymantriidae	Larvae
11.	Leaf webber	*Glyhodes pulverulentalis*	Lepidoptera	Pyralidae	Larvae
12.	Ash weevil	*Myllocerus* sp.	Coleptera	Curculionidae	Grubs
13.	Grasshopper	*Neorthacris acuticeps nilgriensis, Cytocanthacris panacea*	Orthoptera	Aciridae	Nymphs and adults
14.	Stem girdler beetle	*Sthenias grisator* L.	Coleoptera	Cerambycidae	Grubs and adults
15.	Termite/White ant	*Odonototermes sp*.	Isoptera	Termitidae	Workers
16.	White grub	*Holotrichia spp*.	Coleoptera	Melolonthidae	Grubs
17.	Mango stem borer	*Batocera rufomaculata*	Coleoptera	Cerambycidae	Grubs
18.	Bark eating caterpillar	*Indarbela quadrinotata*	Lepidoptera	Metarbelidae	Larvae

2. Important diseases of mulberry crop:

Sr. No.	Common Name	Scientific Name
1.	Leaf spot	*Cercospora moricola*
2.	Powdery mildew	*Phyllactinia corylea*
3.	Leaf rust	*Cerotelium fici*
4.	Root rot	*Macrophomina phaseolina, Fusarium solani, F. oxysporum*
5.	Violet root rot	*Rhizoctonia bataticola*
6.	Stem canker	*Lasidiplodia* (*Btryodiplodia*) *theobromae*
7.	Bacterial blight	*Pseudomonas mori*
8.	Root knot nematode	*Meloidogyne incognita*

II	**Castor cultivation (*Ricinus communis* L.):** The silk produced by *Philosamia ricini* is called Eri silk. Eri silkworm is a polyphagous insect feeds primarily on castor leaves. However, Kesseru (*Heteropanax fragrans* Seem) is used as an alternative food plant during the scarcity of castor leaves. Besides these, some other alternative plants *viz*., Tapioca or Cassava (*Manihot esculenta*), Papaya (*Carica papaya*), Payam (*Evodia flaxinifola*) and Plum*, Plumeria acutifolia* can be used as food plants. Among all, castor is well known and suitable food plant of worm for the successful growth and development.
1.	**Soil and climate:** Red loam/light alluvial soils are suitable. Susceptible to water logged conditions.
2.	**Varieties:** High leaf yielding varieties like GCH-3, GCH-4, GCH-6 and GCH-7.
3.	**Field preparation:** Castor being a deep-rooted crop requires deep summer ploughing. Disc harrowing should be done followed by ploughing to break clods.
4.	**Sowing time:** Irrigated crop - 1st July to 15th August. Rainfed crop - 15th June.
5.	**Seed rate:** Irrigated crop - 5 to 6 kg/ha (dibbling). Rainfed crop - 10 to 12 kg/ha.
6.	**Seed treatment:** Seeds treatment with Carbendazim @ 1g or Thiram @ 3 g /kg of seeds for controlling seed and soil borne diseases.
7.	**Spacing:** Irrigated crop - 90 cm x 60 cm. Rainfed crop - 90 cm x 20 cm.
8.	**Manures and fertilizers:** FYM or compost @ 25 cart loads/ha

Rainfed crop:			
Stage of application	**N kg/ha**	**P_2O_5 kg/ha**	**K_2O kg/ha**
As basal application	20	40	0
At flowering stage i.e. 45 DAS	20	0	0
Total	40	40	0
Irrigated crop:			
As basal application	37.5	50	0
At flowering stage i.e. 45 DAS	37.5	0	0
Total	75	50	0

9.	**Bio- fertilizer:** Seed treatment with Azospirillum or PSB @ 50 gm /kg seed.
10.	**Irrigations:** Irrigated crop: 3-4 irrigations at an interval of 15 to 20 days.
11.	**Weeding and Intercultural operations:** Two hands weeding, one at 30 days of crop growth and the other after 60 days of crop growth should be given. Use of Pendimethalin 0.9 kg a.i./ha immediate after sowing.
12.	**Castor leaves yield:** The castor leaves yield is about 12-14 tonnes leaves/ha/year.

Major insect pests and diseases of castor crop:

1. Insect pests of castor crop:

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
1.	Capsule and Shoot borer	*Conogethes punctiferalis*	Lepidoptera	Pyraustidae	Larvae
2.	Castor semi-looper	*Achaea janata*	Lepidoptera	Noctuidae	Larvae
3.	Slug caterpillar	*Parasa lepida*	Lepidoptera	Cochilididae	Larvae
4.	Hairy caterpillar	*Euproctis fraterna*	Lepidoptera	Lymantriidae	Larvae
5.	Hairy caterpillar	*Portrhesia scintillans*	Lepidoptera	Lymantriidae	Larvae
6.	Tussock caterpillar	*Notolophus posticus*	Lepidoptera	Lymantriidae	Larvae
7.	Hairy caterpillar	*Dasychira mendosa*	Lepidoptera	Lymantriidae	Larvae
8.	Castor butterfly / spiny caterpillar	*Ergolis merione*	Lepidoptera	Nymphalidae	Larvae
9.	Leaf hopper	*Empoasca flavescens*	Hemiptera	Cicadellidae	Nymphs and adults
10.	White fly	*Trialeurodes ricini*	Hemiptera	Aleyrodidae	Nymphs and adults
11.	Thrips	*Retithrips syriacus*	Thysanoptera	Thripidae	Nymphs and adults
12.	Castor gallfly	*Asphondylia ricini*	Diptera	Cecidomyidae	Maggots

2. Diseases of castor crop:

Sr. No.	Common Name	Scientific Name
1.	Seedling blight	*Phytophthora parasitica*
2.	Rust	*Melampsora ricini*
3.	Leaf blight	*Alternaria ricini*
4.	Brown leaf spot	*Cercospora ricinella*
5.	Powdery mildew	*Leveillula taurica*
6.	Stem rot	*Macrophomina phaseolina*
7.	Bacterial leaf spot	*Xanthomonas campestris pv. ricinicola*
8.	Wilt	*Fusarium oxysporum*

Answer the following questions:

1. Which are the three basic three main components of sericulture?
2. Enlist the different varieties of mulberry for irrigated condition.
3. Which spacing is adopted for planting the mulberry garden?
4. How many split are required in application of nitrogenous fertilizer to mulberry crop under irrigated situation?
5. How you will do the pruning to mulberry plants?

6. Which are the common methods of mulberry leaves harvesting?
7. What is the leaf yield potential of mulberry crop?
8. Which are the important insect pest and diseases of mulberry crop?
9. Enlist the different varieties of castor for irrigated condition.
10. Which spacing is adopted for planting the castor crop?
11. Which bio-fertilizers are used in cultivation of food plants?
12. Which are the important insect pest and diseases of castor crop?

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EXERCISE NO. 8

REARING TECHNIQUES OF SILKWORM

Date:

Objectives:

1. To acquaint the knowledge pertaining to rearing equipments used in sericulture unit
2. To study the rearing techniques of mulberry and eri silkworm.
3. To know the important pests and diseases of silkworm with their management.

I. Equipments used in Sericulture Unit:

1.	**Rearing house**: The rearing house should meet certain specification, as the silk worms are very sensitive to weather conditions like humidity and temperature. The rearing room should have proper ventilation, optimum temperature and proper humidity. Dampness, stagnation of air, exposure to bright sunlight and strong wind should be avoided.
2.	**Rearing stand:** Rearing stands are made up of wood or bamboo and are portable. These are the frames at which rearing trays are kept. A rearing stand should be 2.5 m high, 1.5 m long and 1.0 m wide and should have 10 shelves with a space of 20 cm between the shelves. The trays are arranged on the shelves, and each stand can accommodate 10 rearing trays.
3.	**Ant well:** Ant wells are provided to stop ants from crawling on to trays, as ants are serious menace to silk worms. They are made of concrete or stone blocks 20 cm square and 7.5 cm high with a deep groove of 2.5 cm running all round the top. The legs of the rearing stands rest on the centre of well filled with water.
4.	**Rearing tray:** These are made of bamboo or wood so that they are light and easy to handle. These are either round or rectangular.
5.	**Paraffin paper:** This is a thick craft paper coated with paraffin wax with a melting point of 55^0 C. It is used for rearing early stages of silk worms and prevents withering of the chopped leaves and also helps to maintain proper humidity in the rearing bed.
6.	**Foam rubber strips:** Long foam rubber strips 2.5 cm wide and 2.5 cm thick dipped in water are kept around the silkworm rearing bed during first two instar stages to maintain optimum humidity. Newspaper strips may also be used as a substitute.
7.	**Chopsticks:** These are tapering bamboo rods (1cm in diameter) and meant for picking younger stages of larvae to ensure the hygienic handling.
8.	**Feathers:** Bird feathers preferably white and large are important items of silkworm rearing room. These are used for brushing newly hatched worms to prevent injuries.
9.	**Chopping board and Knife:** The chopping board is made up of soft wood it is used as a base for cutting leaves with knife to the suitable size required for feeding the worms in different instar stages.
10.	**Leaf chambers:** These are used for storing harvested leaves. The sidewalls and bottom are made of wooden strips. The chamber is covered on all sides with a wet gunny cloth.

11.	**Cleaning net:** These are cotton or nylon nets of different mesh size to suit the size variations of different instars of the silk worm. These are used for cleaning the rearing beds, and at least two nets are required for each rearing tray.
12.	**Mountages:** These are used to support silkworm for spinning cocoons. These are made up of bamboo, usually 1.8 m long and 1.2 m wide. Over a mat base, tapes (woven out of bamboo and 5-6 cm wide) are fixed in the form of spirals leaving a gap of 5-6 cm. In hindi they are also called ***chandrikes***. Other types of mountage such as **centipede rope mountage**, **straw cocooning frames** etc. are also used.
13.	**Feeding stands:** Wooden stands used for holding the trays during feeding and bed cleaning.
14.	**Hygrometers and Thermometers:** These are used to record humidity and temperature of the rearing room.
15.	**Feeding basins, sprayer, and leaf baskets may also be required.**

II. Rearing techniques of silkworms:

II	Rearing techniques of silkworms
A.	**Rearing of mulberry silkworm:** Silkworms must be reared with utmost care since they are susceptible to diseases. Therefore, to prevent diseases, good sanitation methods and hygienic rearing techniques must be followed. The appliances and the rearing room should be thoroughly cleaned and disinfected with 2-4% formaldehyde solution. Room temperature should be maintained around 25^0 C.
1.	**Procurement of quality seeds:** Seeds are obtained from grainages, which are the centres for production of disease free seeds i.e. DFL of pure and hybrid races in large quantities.
2.	**Quality food**: Younger larvae (I and II stage) instar are to be given tender succulents leaves with high moisture content and whereas older instars fed with mature but soft leaves with lesser moisture content.
3.	**Brushing:** The process of transferring the silkworm to rearing trays is called brushing. Suitable time for brushing is about 10.00 am. In case of eggs prepared on egg cards, the cards with the newly hatched worms are placed in the rearing trays or boxes and tender mulberry leaves are chopped into pieces and sprinkled over egg cards. In case of loose eggs a net with small holes is spread over the box containing the hatched larvae and mulberry leaves cut into small pieces are scattered over the net. Worms start crawling over the leaves on the net; the net with worms is transferred to rearing tray.
4.	**Preparation of feed bed and feeding:** After brushing, the bed is prepared by collecting the worms and the mulberry leaves together by using a feather. The bed is spread uniformly using chopsticks. The first feeding is given after two hours of brushing. Feed bed is a layer of chopped leaves spread on a tray or over a large area. The first and second instar larvae are commonly known as **chawki worms**. For chawki worms, paraffin paper sheet is spread on the rearing tray. A second paraffin paper sheet is spread over the first be d. In between two sheets water soaked foam rubber strips are placed to maintain humidity. The 4^{th} and 5^{th} instars are reared in wooden or bamboo trays by any of the three methods: *viz*., shelf-rearing, floor-rearing and shoot-rearing. In shelf rearing, the rearing trays are arranged one above the other in tiers on a rearing stand which can accommodate 10 -11 trays. The larvae have good appetite at first feeding stage and comparatively little appetite at sparse and moderate eating stages. They eat voraciously during active stage to last feeding stage after which they stop feeding.
5.	**Bed cleaning:** Periodical removal of left over leaves and worms' excreta may be undertaken and is referred to as

	bed cleaning. It is necessary for proper growth and proper hygiene. Four methods are adopted: conventional method, husk method, net method, and combined husk and net method.
6.	**Moulting:** Remove the paraffin paper. Larvae should be evenly spread in the rearing bed 6-8 hrs before settling the moulting. Provide proper ventilation to avoid excess humidity in rearing room. Provide charcoal stove/heater to raise the room temperature during winter season. Apply lime powder 60 minutes before resumption of feeding daily during rainy and winter season to avoid Muscardine disease infection.
7.	**Mounting:** Transferring mature fifth instar larvae to mountages is called mounting. When larvae are fully mature, they become translucent, their body shrinks, and they stop feeding and start searching for suitable place to attach themselves for cocoon spinning and pupation. They are picked up and put on mountages. After the compact shell of the cocoon is formed, the shrinking larva wraps itself and detaches from the shell and becomes pupa or chrysalis.
8.	**Harvesting of cocoon*s*:** The larva undergoes metamorphosis inside the cocoon and becomes pupa. In early days, pupal skin is tender and ruptures easily. Thus, early harvest may result in injury of pupa, and this may damage the silk thread. Late harvest has a risk of threads being broken by the emerging moth. It is, therefore, crucial to harvest cocoons at proper time. Cocoons are harvested by hand. After harvesting the cocoons are sorted out. The good cocoons are cleaned by removing silk wool and faecal matter and are then marketed. The cocoons are sold by farmers to filature units through Cooperative or State Govt. Agencies. The cocoons are priced on the basis Rendita and reeling parameters. **Rendita** is defined as number of kg of cocoon required for the production of 1 kg of raw silk.
9.	**Post cocoon processing:** It includes all processes to obtain silk thread from cocoon. **(a) Stifling:** The process of killing pupa inside cocoon is termed as stifling. Good-sized cocoon 8-10 days old are selected for further processing. Stifling is done by subjecting cocoon to hot water, steam, dry heat, sun exposure or fumigation, etc. **(b) Reeling:** The process of removing the threads from killed cocoon is called reeling. **Denier** is a unit of measurement that is used to determine the fiber thickness of individual threads or filaments. Denier expresses weight in grams of 9000 meter length of the material.
B.	**Rearing of eri silkworm** Disease free seed cocoons are obtained from Grainages or Agencies and reared fully indoors. Healthy cocoons are spread on bamboo trays in cool dark room. On hatching, active males are separated from passive females and are then allowed to mate in quiet dark room. Fertilized females are then tied to '*kharikas'*(Egg laying device) by passing a thread around the shoulder joint of the right wings. *Kharikas* are then suspended from a string. Eggs are laid within 24 hours on *Kharika* are normally selected for rearing. The eggs are white, oval and covered with a gummy substance, which makes them adhere to one another.
1.	**Rearing house for Eri culture:** Eri silkworms are reared indoor. Rearing house should be ventilated and fly proof.
2.	**Disinfection and prophylactic measures:** Disinfection made before and after each rearing is considered the key for a successful cocoon harvest. Disinfect the rearing house at least 7 days before and soon after the rearing. Wash the rearing houses and appliances with 5 % bleaching powder solution before rearing. Sprinkling of 2 % bleaching powder-lime mixture in the surroundings of the rearing house is equally effective.
3.	**Egg incubation:** Incubate DFLs at 24-26°C temperature and 75-85% R.H.

4.	**Brushing:** Hands should be washed with 2% formalin solution and then with water. Brush newly hatched worms on tender leaves during morning hours. Use paraffin paper and water soaked foam pad in rearing tray to maintain temperature and humidity.
5.	**Feeding:** Feed 1st instar worms on tender, 3rd and 4th instar on semi-matured and 5th instar on matured leaves. Feed the worms with minimum 4 times a day.
6.	**Bed cleaning:** This work is carried out at regular interval in the same as adopted for the mulberry silkworm. The growing worms undergo four moults and have five instar stages. The 5th instar mature larvae stop feeding and start searching for a proper place to spin the cocoon. At this stage, the mature worms are picked up and transferred to mountages (*Chandrikes*).
7.	**Bed cleaning:** Resort to bed cleaning daily. Nylon net can be used for easy bed cleaning.
8.	**Late stage rearing:** Rear maximum 300 number of 5th instar worms per 3 feet x 3 feet diameter tray. Low cost bamboo platform rearing equipment is the best for rearing late stage worms considering the limited rearing space and frequent bed cleaning. The structure with 6ft (L) x 5.5 feet (H) x 3 feet (W) dimensions can accommodate 25-30 DFLs.
9.	**Ripe (Mature) worm collection:** Ripe worms become yellowish white and start roaming for selection of site for cocoon formation. While picking up the matured worms and rubbing in between fingers, a sound of hollowness is produced in eri silkworm. Mature worms are collected and put to cocooning mountages.
10.	**Post cocoon processing:** Stifling is done by spreading and exposing the cocoons to sun for 1-2 days. For degumming, cocoons are tied in a cloth sac and dipped in boiling soda solution. After sufficient boiling, the cocoons are taken out, washed with water several times to remove soda, squeezed to remove water and then spread on mats to dry. Being open mouthed, the thread of the cocoons is discontinuous. So, the thread can only be spun and not reeled.

III Natural enemies of silkworm:

A. Important pests of silkworm with their management:

Pests	Nature of Damage	Management
Uzi fly *Exorista sorbillans* (Tachinidae: Diptera) (Endo-parasitoid of silkworm)	• The flies lay eggs on grown up larvae of silkworm and maggots on hatching feed the body contents of caterpillar. • Mature maggot causes reduction in yield of cocoons and cocoon quality. • Also causes death of silkworm larva. • Presence of creamy white oval eggs on the skin of larvae in the initial stage. • Presence of black scar on the larval skin. • Silkworm larvae die before they reach the spinning stage (if they are attacked in the early stage). In later stage, pierced cocoon is noticed.	• Prevent fly's access to silkworms by mechanical means. • Fly proof rooms/doors/ventilators. • All crevices of the rooms should be closed to prevent maggots pupating in the soil. • Dusting of China clay @ 3g/100 on spinning larvae before mounting.

Beetles *Dermestes cadeverinus* (Dermestidae: Coleoptera)	• The adults and grubs are attracted to smell of the cocoons. • They eat the cocoons, enclosed pupae and often the eggs of silkworms. • The females lay eggs in the crevices, organic matter and wooden boards. • Grubs and adults bore into the cocoons and eat the dried pupae, attack pierced and melted cocoons stored within the grainage. • Presence of small holes (pierced cocoons) in the pupae and abdominal parts are damaged in the adult months.	• Closure of cracks and crevices. • Thorough cleaning of rearing room. • Fumigation of rooms with methyl bromide. • Store the pierced cocoons in a separate room. • Avoid long storage of pierced cocoons. • Sun dry the pierced cocoons once in a week.
Ants (Hymenoptera)	The ants attack silkworms in rearing trays.	• Legs of the rearing stands should be dipped in ant wells (water + kerosene). • Use of ash or kerosene at the handles of the mountages at the time of spinning.
Lizards, birds, rats and squirrels	• They feed on silkworms. • Mammals predate on pupae by biting open the cocoons.	• Rearing rooms should be kept free from lizards. • Setting of traps for rat and squirrel control. • Scaring of birds from the vicinity.

B. Important diseases of silkworm with their management:

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
Pebrin disease (Protozoa transmitted) (*Nosema bombycis)*	Eggs, Larvae, pupae, adults Mode of infection: Ingestion of spores	• It is a chronic disease. • Eggs laid by moth are fewer and do not firmly attach to the egg sheet. • Peeper like black spots. • Laying of unfertilized and dead eggs. • Diseased larvae have poor appetite, retarded growth, undersized and flaccid. • Larvae are comparatively paler, translucent and delays to moult. • Silk gland will have white pustules on its surface.	• Mother moth examination. • Use of disease free females. • Sterilization of eggs with 2% formalin. • Destruction of infected eggs and females. • Bed disinfectant: Vijetha powder

		• Dead larvae remain rubbery for some time and then turn black. • Diseased pupa may develop black markings on the surface. • Moth appears malformed. The wings are stunted and crippled • The infection spreads to successive generation through eggs of diseased moth (transovarial transmission). ***Responsible factor*:** • Infected seeds (eggs)	
Flacherie disease (Bacteria transmitted) *(Bacillus bombysepticus)*	Larvae Mode of infection: Ingestion of spores	• Loss of appetite, semisolid excreta, becomes lethargic. • Skin becomes flaccid body purification and emission of foul smell. • Larvae vomits gut juice and develop dysentery. ***Responsible factor*:** • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	• Proper incubation of eggs. • Proper rearing conditions. • Disinfectant: Slaked lime solution 0.3% • Bed disinfectant: Vijetha powder
Grasserie disease (Virus transmitted) (Nuclear Polyhedrosis Virus) Milky disease	Larvae Mode of infection: Ingestion of polyhedra (Chrystal virus particle)	• Swelling of inter segmental region and easy rupture of skin. • The integument will be fragile and breaks easily oozing turbid milky fluid. • Body fluid becomes thick and cloudy and they die. • The larvae do not settle for moult and their integument become shining ***Responsible factor*:** • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	• Avoidance of injury. • Disinfection of seed production unit, appliances, silkworm rearing house surroundings and silkworm egg surface. Disinfectant: Slaked lime solution 0.3% • Bed disinfectant: Vijetha powder
Muscardine disease (Fungal transmitted) White Muscardine	Larvae/ pupae/ adults	• Larvae loose appetite, become inactive and flaccid on death. • Hyphae come out inter-segmental membranes. • Body becomes too hard. • Mummified larvae vomit and shows	• Proper rearing conditions. • Sterilization. • Formalin 3% or Bleaching powder 2% or Slaked lime

(Beauveria bassiana) **Green Muscardine** *(Spicaria prasina)* **Yellow Muscardine** *(Iscaria farinosei)*	Mode of infection: Penetration of skin by germinating spores of conidia	diarrhea like symptoms. ***Responsible factor*:** • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	solution 0.3% as disinfectant. • Bed disinfectant: Vijetha powder

Answer the following questions:

1. How many eggs are present in 1 DFL?
2. Why paraffin paper is used in sericulture unit?
3. Give the functions of the following:
   a) Rearing tray b) Foam rubber strips c) Chopsticks d) Feathers e) Leaf chambers
4. Why brushing is done rearing of silkworm?
5. What you understand by rendita and Denier?
6. Which are precautions to be taken during rearing of larvae?
7. Why bed cleaning is done in sericulture unit?
8. Which are the posts cocoons processing techniques?
9. Mention the important pest and disease of silkworm with their damage symptoms.

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EXERCISE NO. 9

SPECIES OF LAC INSECT AND THEIR HOST PLANT IDENTIFICATION

Date:

Objectives:

1. To study the biology of lac insect and different types of lac products.
2. To acquaint the knowledge in context to lac host and different strains of lac insect.
3. To study the scientific cultivation practices of lac insect host plant.
4. To study the natural enemies of lac insect.

Lac is a natural resinous secretion by an insect, *Kerria lacca* (Kerr.). Millions of these sessile lac insects sustain their life on specific host plants, secreting resin as their body covering, which eventually harvested in the form of resin, dye and wax of commercial importance.

Taxonomic classification of lac insect:

Domain: Eukarya; Kingdom: Animalia; Phylum: Arthropoda; Class: Insecta; Order: Hemiptera; Super-family: Coccoidea; Family: Kerriidae; Genus: *Kerria;* Species: *K. lacca*

I.	**Life cycle of lac insect:** Lac insect is a minute crawling scale insect which inserts its suctorial proboscis into plant tissue, sucks juices, grows and secretes resinous lac from the body. Its own body ultimately gets covered with lac in the so called 'CELL'. Lac is secreted by insects for protection from predators. It includes three stages; egg, nymph and adult.
1.	**Egg:** The eggs are laid by the female within the lac-cell. It lays about 200-500 eggs which may be fertilized or unfertilized. An individual egg is pinkish in colour which changes into brown after sometimes. The female generally lays well developed eggs which hatch within a few hours. Thus, the lac insect has ovoviviparous mode of reproduction. After six weeks, the eggs are hatched into first instar larvae called crawlers.
2.	**Nymphs:** The crimson red coloured nymphs, referred to as 'crawlers'. Boat shaped nymphs are very small in size (0.5 mm) and abdomen is provided with a pair of caudal setae. The nymphs moult thrice before reaching maturity. Larvae moult in their respective cells. During first moult both male and female nymphs lose their appendages, legs and eyes. Following this moult, dimorphism appears in their cells. The second stage larva undergoes pseudo-pupation for a brief time, whereby it changes into adult stage. Inside the male cells, the male nymph casts off their second and third moult and matures into adults.
3.	**Adult** In case of males the growth is more on the longitudinal axis and in females the growth is more in vertical axis. The life span of the female is longer than that of the males. Most of the lac is secreted by the females. The adult male is pinkish red in colour and smaller in size than the female insect. Males have antennae, legs and a pair of wings. The male lac insect may be either winged with one pair of hyaline wing on its thorax or wingless (apterous). A pair of white elongated caudal seta or filament is present on either side of this sheath. They survive only 3-4 days and die after copulation. The female is pinkish in colour and about 1.5 mm in length. The ventral surface of the body is flat while dorsal surface is convex. The female is deprived of eyes, legs and wings. Antennae are vestigeal, small and 3-4 segmented. The mouth parts are piercing and sucking type and rostrum is two segmented. The female remains attached at a point and sucks the juice from the host. Mesothorax is provided with an appendage on which spiracles open. The abdomen is round and on the dorsal surface, a spine is provided. The last abdominal segment is two segmented and anus is fringed.

4.	**Fertilization** Lac insects are ovoviviparous types of fertilization. Parthenogenesis is known to occur when unfertilized eggs are directly hatched into nymphs. It is common in Kartiki crop of Rangeeni Strain.

Lac hosts: Host plants such as *Butea monosperma* (Palas), *Schleichera oleosa* (Kusum) and *Ziziphus mauritiana* (Ber) are of major importance. In addition to these host plants, a bushy host plant species, *Flemingia semialata* Roxb. (Leguminosae: Papilionaceae), has been identified and field tested as a potential fast growing host. However, *Prosopis juliflora* (in Gujarat areas) are expected to enhance Kusmi lac cultivation.

Strains of lac and lac crops:

Two strains of the lac insects are recognized in India, the ***Rangeeni*** and ***Kusmi.*** Each strain completes its life cycle twice a year but the seasons of maturity differ considerably. In Mysore, the Rangeeni strain completes their life cycle in 13 months on Jallari (*Shorea talura).* There are four lac crops in a year that are named after the Hindi months. The following table summarizes the information about four lac crops.

Strains of lac and lac crops

Sr. No.	Inoculation with Lac Swarming larva	Lac Host Plant	Weather	Seed Inoculation	Emergence of male insects	Crop harvested	Female insects mature and give rise to swarming larvae	Time (In month)
A.	**RANGEENI CROPS**							
i	Katki crop (June –July)	Palas	Rainy Season	June-July	Aug-Sept	Oct-Nov	Oct-Nov	4
ii	Baisakhi crop (Oct – Nov)	Palas	Summer	October - Nov	Feb-March	April-May Leaving a certain amount of lac on trees to mature and act as brood in July	June-July	6-8
		Ber	Summer	October - Nov		May-June		6
B.	**KUSUMI CROPS**							
i	Aghani crop (June-July)	Ber	Winter	June-July	September	Dec-Jan	Jan-Feb	6
ii	Jethwi crop (Jan-Feb)	Kusum	Summer	January-February	March - April	June –July	June –July	6

II.	**Scientific method of lac cultivation**
1.	**Selection of suitable host plants:** The host trees should be properly pruned to put forth young succulent shoots before inoculation. Fairly fast growing. Lower sap density. Well adapted to pollarding.
2.	**Selection of suitable site for lac cultivation:** The sites for lac host plantation should be in such a place where free circulation of air around the host is assured. Cultivation should not be attempted at places where fire susceptibility is there. When starting cultivation in new areas having lac host. It is always desirable to prune them before infection to ensure good lac production.
3.	**Types of pruning in lac host plants** Two types of pruning/ coppicing have been recommended for lac culture. **(a) Apical/ light pruning:** Branches less than 2.5 cm diameter should be cut from base and branches more that 2.5 cm diameter should be sharply cut leaving a stump of 30-45 cm from the base e.g. Palas, Kusum and Ber. **(b) Basal / heavy pruning**: Branches having less than 7 cm thickness should be removed from the base, whereas thicker branches should be cut at a place where it has a diameter of 7 cm. In quick growing bushy host, pruning should be done at a height of 10-15 cm from the ground level e.g. *Flemingia macrophylla, F. semialata.* **Pruning time**: • February - Katki crop • April for raising the *Baisakhi* crop, *Rangeeni* host, ber and palas. • June-July and January – February - kusum
4.	**Infestation of lac hosts (inoculation):** Brood lac is mature lac where from the young insects are ready to come out within the time specified. **(a) Collection of brood lac:** Lac sticks, having mature female insects ready to give rise to the next generation are called *brood lac*. The cutting of brood lac should be taken up at the correct time keeping in view the swarming period *i.e*. the expected date of larval emergence. **(b) Selection of brood lac:** Healthy lac with the minimum signs of predator and parasitoid damage is selected. **(c) Inoculation of brood lac:** This operation includes putting of bundles of brood lac (*lac sticks containing gravid females*) in the host twigs for allowing young lac larvae (*crawlers*) to come out of their mother cells and settle on the host plant.
5.	**Removing of used-up broodlac sticks (*Phunki*):** Used up broodlac sticks after complete emergence of lac larvae from female cells is called *phunki.* This operation should be done to prevent access of the insect predators and parasitoids of lac insect to new lac crop and to avoid wastage of lac after drying up of phunki and prevent its falling on ground. It should be done as soon as emergence of lac crawlers is over. Generally the emergence of lac larvae from the brood lac ceases after three weeks. The phunki lac so removed is scrapped off thereafter in the brood lac for more than three weeks from the start of larval emergence to avoid emergence of enemy insects. Phunki bundles are pulled down from the trees with the help of pole mounted phunki hook or by climbing on trees.
6.	**Harvesting:** Harvesting is the process of collection of lac from host trees. Two type of harvesting process is used in most of the regions; Ari lac harvesting and mature harvesting. It is done by cutting the lac encrusted twigs when crop is mature. **A. Ari lac harvesting:** Immature harvesting and collection of lac before swarming is known as 'Ari lac'. Recommended only in rangeeni strain.

	B. Mature harvesting: In mature harvesting lac is collected after swarming. A yellow spot develops on the posterior side of lac cell towards crop maturity. This spot spread forwards until it covers half of the cell. The harvesting periods of different crops are different. The katki crop in Oct./Nov.; baisakhi in May/June; aghani in Jan/Feb.; and jethwi in June/July. **Mature lac harvesting is of two types in practice as:** **(a) Partial harvesting:** This harvesting is performed when surplus brood lac is on the tree and sufficient branches are available on the tree for next generation. It should be done in the month of January/February or June/July. **(b) Complete harvesting:** In this process lac is fully harvested from the plant and plant is pruned and left for new shoot emergence. Lac crop should be harvested only when mature.
7.	**Scrapping:** Removal of lac resin incrustation from lac host stick is called scraping. **Benefits scraping:** Help for quick dry and minimize the moisture content. Save the lac loss from lac predators. Easy storage. Escape from fungal attack. Hidden insect stages can be killed and removed. Increases the storage life.

III. Natural enemies of Lac insect:

It has been estimated that on an average 30 to 40 per cent of the lac cells are destroyed by insect enemies of lac crop.

1. Parasitoids: All parasitoids belong to the order hymenoptera of class Insecta.

Table. 4: List of parasitoids associated with lac insect, *Kerria lacca*

Sr. No.	Name of the parasitoid	Family
1.	*Anicetus dodonia*	Encyrtidae
2.	*Atropates hautefeuilli*	Encyrtidae
3.	*Aphrastobracon flavipennis*	Encyrtidae
4.	*Bracon greeni*	Encyrtidae
5.	*Campyloneurus indicus*	Encyrtidae
6.	*Coccophaqus tchirchii*	Aphelinidae
7.	*Erencyrtus dewitzi*	Encyrtidae
8.	*Eupelmus tachardiae*	Eupelmidae
9.	*Eurymyiocnema aphelinoides*	Aphelinidae
10.	*Lyka lacca*	Encyrtidae
11.	*marietta javensis*	Aphelinidae
12.	*Parageniaspis indicus*	Encyrtidae
13.	*Parechthrodryinus clavicornis*	Encyrtidae
14.	*Protyndarichus submettalicus*	Encyrtidae
15.	*Tachardiaephagus tachardiae*	Encyrtidae
16.	*Teachardiobius nigricans*	Encyrtidae
17.	*Aprostocetus(Tetrastichus) purpureus*	Eulophidae

2. Predators: The predators damage up to 30 to 35 percent to the lac cells in a crop.

List of predators associated with lac insect, *Kerria lacca*

Sr. No.	Insect Predator	Order	Family
1.	*Eublemma amabilis*	Lepidoptera	Noctuidae
2.	*E. coccidiphaga*	Lepidoptera	Noctuidae
3.	*E. cretacea*	Lepidoptera	Noctuidae
4.	*E. scitula*	Lepidoptera	Noctuidae
5.	*Pseudohypatopa pulverea*	Lepidoptera	Blastobasidae
6.	*Catablemma sumbavensis*	Lepidoptera	Blastobasidae

7.	*Cryptoblabes ephestialis*	Lepidoptera	Blastobasidae
8.	*Phroderces falcatella*	Lepidoptera	Cosmopterygidae
9.	*Lacciferophaga yunnanea*	Lepidoptera	Momphidae
10.	*Chrysopa madestes*	Neuroptera	Chrysopidae
11.	*C. lacciperda*	Neuroptera	Chrysopidae
12.	*Berginus maindroni*	Coleoptera	Mycetophagidae
13.	*Silvanus iyeri*	Coleoptera	Cucujidae
14.	*Tribolium ferrugineum*	Coleoptera	Tenebrionidae
15.	*Phyllodromia humbertiana*	Dictyoptera	Blattellidae
16.	*Ischonoptera fulvastrata*	Dictyoptera	Blattellidae

Organizing exposure visit to research/training institutes of lac insect:

Exposure Visit is useful to gain the knowledge and experience of the work culture and provides an agro-industrial exposure to the students for developing their career in the Agro based industries. It is a method by which a group gets together for the purpose of seeing an improved performance or result of practice in actual situations. This requires the group to move out of the area for a considerable period with a pre-decided programme. A field visit will be organized and the students will record their observations.

1. Place of visit:
2. Purpose of visit:
3. Which are the important equipments that you have observed during the visit?
4. Which problems of research/training institutes are identified in the field visit?
5. What interesting information is noted during visit?

Answer the following questions:

1. Give the morphological characteristics of different stages of lac insect
   a) Eggs b) Nymph c) Adult
2. Which are the products of lac found in India?
3. Which is suitable host plant for cultivation lac insect?
4. Mention the different strains of lac insect.
5. Enlist the different types of pruning method adopted in lac host plants.
6. Enlist the different natural enemies of lac insect.
7. Give the comments about exposure visit to research/training institutes.

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EXERCISE NO. 10

PREDATORS AND PARASITOIDS USED IN PEST CONTROL PROGRAMME

Date:

Objectives:

1. To know the good qualities of predators and parasitoids.
2. To study the important insect orders bearing predators and parasitoids used in pest management programme.

Qualities of a successful parasitoid in biological control programme:

A parasitoid should have the following qualities for its successful performance. It should be adaptable to environmental conditions in the new locally. It should be able to survive in all habitats of the host. It should be specific to a particulars species of host or at least a narrowly limited range of hosts. It should be able to multiply faster than the host. It should be having more fecundity. Life cycle must be shorter than that of the host. It should have high sex ratio. It should have good searching capacity for host. It should be amendable for mass multiplication in the labs. It should bring down host population within three years. There should be quick dispersal of the parasitoid in the locality. It should be free from hyperparasitoids.

Kinds of Parasitism

I. **Parasite:** A parasite is an organism which usually much smaller than its host and a single individual usually does not kill the host.

II. **Super parasitism:** It is type of parasitism where more individuals at of the same species are present in a single host and than can complete development in a normal way. Generally survive one per host. Phenomenon of parasitization of an individual host by more larvae of single species that can mature in the host. E.g. *Apanteles glomeratus* on *Pieris brassica, Trichospilus pupivora* on *Opisina arenosella*.

III. **Multiple parasitisms:** It is the type of parasitism where the host is attacked by two or more species of parasitoids. Usually death results in the death of less aggressive species of parasitoids. Phenomenon of simultaneous parasitization of host individual by two or more different species of primary parasites at the same time. E.g. *Trichogramma, Telenomous and Tetrastichus* attack eggs of paddy stem borer *Scirpophaga incertulas*. Super parasitism and multiple parasitisms are generally regarded as undesirable situations since much reproductive capacity is wasted.

IV. **Hyper parasitism:** It is type of parasitism in which a parasitoid attacks another parasitoid. Secondary parasitoids is harmful, while tertiary useful. When a parasite itself is parasitized by another parasite.E.g. *Goniozus nephantidis* is parasitized by *Tetrastichus israeli,* Most of the Bethylids and Braconids are hyper parasites.

V. **Simple parasitism** irrespective of number of eggs laid the parasitoid attacks the host only once. E.g. *Apanteles taragamae* on the larvae of *Opisina arenosella, Goniozus nephantidis.*

Insect predator qualities:

A predator generally feeds on many different species of prey, thus being a generalist or polyphagous nature. A predator is relatively large compared to its prey, which it seizes and devours quickly. Typically individual predator consumes large number of prey in its life time E.g. A single coccinellid predator larva may consume hundreds of aphids. Predators kill and consume their prey quickly, usually via extra oral digestion. Predators are very efficient in search of their prey and capacity for swift movements. Predators develop separately from their prey and may live in the same habitat or adjacent habitats.

I	**Parasitoid orders**
A.	**Order: Hymenoptera:** The ovipositor originates and protrudes ventrally from the abdomen and is used to insert eggs into their hosts. There are three super families.
a.	**Super Family: Ichneumonoidea:** • Possess long and filiform antennae. • Wings are veined.
1.	**Family: Ichneumonidae:** • Eg. *Eriborus trochanteratus,* a larval parasitoid on coconut black headed caterpillar, *Opisina arenosella.* • Antennae longer with more than 16 segments. • Trochanter two segmented. • Possesses two recurrent veins and rarely one. • Abdomen three times as long as the rest of the body. • Ovipositor longer than the body. • Large slender black, yellow or reddish yellow insects. • Larvae are endo or ecto parasitic on many groups of insects and spiders.
2.	**Family: Braconidae:** • Eg. *Bracon brevicornis,* a larval parasitoid on *O. arenosella, Chelonus blackburni,* egg larval parasitoid on cotton spotted bollworms, *Earias* spp. • Adults are relatively small, more stout bodied than ichneumonids. • Abdomen is about as long as the head and thorax combined. • Not more than one recurrent vein. • Adults not as bright as ichneumonids. • Mostly endoparasitic on lepidopteran larvae.
b.	**Super Family: Chalcidoidea:** • Mostly smallest parasitoids and gregarious. • Antennae geniculate. • Abdomen very short or globular with very slender propodeum. • Wings without veins.
1.	**Family: Chalcididae:** • Eg. *Brachymeria nephantidis*a larval parasitoid on *O. arenosella.* • Minute insects. • Abdomen humped. • Hind femur enlarged and toothed. • Wings are not folded longitudinally when at rest. • Ovipositor straight and short. • Parasitic on Lepidoptera, Diptera anpl Coleoptera.
2.	**Family: Trichogrammatidae:** • Eg. *Trichogramma chilonis,* an egg parasitoid on many lepidopterous pests. • Mostly egg parasitoids. • Minute insects (0.3 to 1.0 mm long) with three segmented tarsi and broad and elongated fore wings with rows of microscopic hairs on them. • Hind wings reduced with hairs.

3.	**Family: Eulophidae:** • Eg. *Trichospilus pupivora* and *Tetrastichus israeli,* pupal arasitoids on *O. arenosella.* • Adults have four segmented tarsi. • Many have brilliant metallic colouring. • Males of many species have pectinate antennae. • Mostly parasitic on aphids and scales and some are on pupae of Lepidoptera.
c.	**Super family: Bethyloidea:** • Smaller than ichneumonoidea and larger than Chalcidoidea.
1.	**Family: Bethylidae:** • Eg. *Parasierola (= Goniozus) nephantidis,* a larval parasitoid on *O. arenosella.* • Small to medium sized, usually dark coloured wasps. • Females of many species are wingless and antlike in appearance. • In a few species, both winged and wingless forms occur in each sex. • Parasitic on Lepidoptera and Coleoptera.
B.	**Order: Diptera**
1.	**Family: Tachinidae:** • Eg. *Sturmiopsis inferens,* a larval parasitoid on sugarcane shoot borer, *Chilo infuscatellus.* • Large bristle flies. • Eggs may be macrotype or microtype. • Macrotype eggs are laid directly on the host's body usually attached to the neck region by a glutinous secretion. • Eg. *Spoggosia bezziana* on *O. arenosella.* • Microtype eggs are laid orj the host plant and the host larvae feeding on the plant tissue ingest them.
C.	**Order: Lepidoptera**
1.	**Family: Epiricanidae:** • Eg. *Epiricania melanoleuca.* • Parasitic on nymphs and adults of sugarcane leafhopper, *Pyrilla perpusilla.*

II	**Predator orders**
A.	**Order: Odonata**
a.	**Sub order: Anisoptera Eg. Dragon fly** **Sub order: Zygoptera** Eg. Damsel fly • Relatively larger sized insects. • Immature stages are aquatic (naiads) feeding on aquatic insects. • In naiads, labium is modified into a prehensile organ called mask for catching the prey. • Adults feed on midges, mosquitoes, flies and small moths. • Adults are capable of catching prey during flight with the help of basket shaped legs.
B.	**Order: Dictyoptera**
1.	**Family: Mantidae:** • Preying mantids are large elongate insects. • Nymphs and adults are cryptically coloured with long prehensile raptorial forelegs. • Highly predaceous feeding on variety of insects like flies, grasshopper and many caterpillars Eg. *Mantis religiosa.*

C.	**Order: Hemiptera**
1.	**Family: Reduviidae:** • Assassin bugs or cone nose bugs or kissing bugs. • Usually blackish or brownish in colour. • The beak or proboscis is short and three segmented. • Most are predaceous and some are blood sucking. • Both nymphs and adults are predaceous. • Eg. *Harpactor costalis* on the red cotton bug *Dysdercus cingulatus.*
2.	**Family: Pentatomidae:** • Stink bugs. • Bugs are shield shaped with 5 segemented antennae. • Some ofthe species are predaceous on lepidopterous larvae. • Both nymphs and adults are predaceous. • Eg. *Eucanthecona furcellata* on the larvae of red hairy catepillar, *Amsacta albistriga* and gram caterpillar, *Helicoverpa armigera.*
3.	**Family: Belostomatidae:** • Giant water bug. • Elongate oval and somewhat flattened with raptorial forelegs. • Feed on variety of aquatic insects.
4.	**Family: Miridae**: • Elongated soft bodied insects. • A few species are predaceous. • Eg. Green mirid bug, *Cyrtorhinus iividipennis* feeds mainly on the eggs and early stage nymphs of green leaf hopper (GLH), brown plant hopper (BPH) and white backed plant hopper (WBPH) in rice.
5.	**Family: Veliidae:** • Ripple bugs. • Aquatic insects living on the surface of water. • Brown or black in colour. • Eg. *Microvelia atrolineata* feeding on the first instar caterpillar of lepidopteran pests and GLH, BPH and WBPH in rice ecosystem.
D.	**Order: Neuroptera**
1.	**Family: Myrmeliontidae:** • Antlions. • Larvae construct pit falls and remain buried in the soil. • Feed on the ants and other insects that fall into the pits. • Feed by inserting the mandibulo - suctorial mouth parts into the prey and sucking the internal contents.
2.	**Family: Chrysopidae:** • Aphid wolf, aphidlions or green lace wings. • Adults are green in colour with golden or copper coloured eyes. • Feed on more than 18 jamilies of insects. • The larvae are predaceous mainly on aphids and also on eggs of lepidopteran insects, psyllids, coccids, thrips and mites. • Larvae have sharp mandibles. • The eggs of aphidlions are stalked (pedicellate).

E.	**Order: Diptera**
1.	**Family: Asilidae:** • Robber flies. • Adults are mostly elongate with tapering abdomen. • Body is covered with dense hairs. • Legs are long, strong and well developed. • Adults are predaceous and attack a variety of insects like wasps, bees, grasshoppers, flies etc. • Mouth parts are piercing type. They feed by sucking the body fluid of the prey.
2.	**Family: Syrphidae:** • Hover fly adults are brightly coloured and resemble various bees and wasps. • Good pollinators. • Maggots are green in colour and feed on aphids by sucking their body fluids.
F.	**Order: Coleoptera**
1.	**Family: Coccinellidae:** • Lady bird beetles. • Beetles are small, oval, convex and often brightly coloured. • Grubs are elongate, somewhat flattened and covered with minute tubercles or spines. • Adults and grubs feed on aphids, coccids, mealy bugs, whiteflies and other soft bodied insects. • Except one or two species in the family all are predaceous. • Eg. *Rodolia cardinalis* on cottony cushion scale, *Icerya purchase.*
2.	**Family: Carabidae:** • Ground beetles. • Dark in colour and shiny and somewhat flattened. • Most of them feed on caterpillars. • Eg. *Anthia sexguttata, Ophionea indica.*
3.	**Family: Cicindelidae:** • Tiger beetles. • Beetles are very active and brightly coloured. • They run and fly rapidly. • Both adults and grubs are predaceous. • Adults capture the prey with sickle shaped mandibles. • Eg. *Cichidela* spp.
4.	**Family: Staphylinidae:** • Rove beetles. • Eg. *Paederus fuscipes* feeds on rice leaf folder.
G.	Order: Hymenoptera
1.	**Family: Vespidae:** • Wasps collect various insects and feed their larvae with them. • Mudwasps construct nests made of mud and provide caterpillars for the young ones in the nest.
2.	**Family: Sphecidae:** • Digger wasps construct nests made of mud and feed its young ones with insect caterpillars.
3.	**Family: Formicidae:** • About half the members of the family are predaceous upon insects.

Answer the following questions:

1. Define the Biological control and give 10 examples of successful bio-control agents.
2. Which are the three pillars of biological control of insect pests?
3. Give the qualities of a successful parasitoid in biological control programme.
4. Write about the kinds of parasitism.
5. Which are the good qualities of insect predators?
6. Enlist the important orders of insect bearing parasitoids with their target host.
7. Give the important orders of insect bearing predators with their target host.
8. Why *T. japonicum* is more effective against paddy stem borer than *T. chilonis*?
9. Why Braconids are considered as limitation of bio-control laboratory?
10. Give the name of one predator and one parasitoid present in Lepidoptera order and also mention name of host insect for both natural enemies.

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EXERCISE NO. 11

MASS PRODUCTION TECHNIQUES OF BIOAGENTS

Date:

Objectives:

1. To study the mass production of factitious host, *Corcyra cephalonica*.
2. To know the mass production of *Trichogramma chilonis* and *Chrysoperla zastrowi sillemi.*
3. To give the exposure visit to students at Bio-control Laboratory.

A large numbers of predators, parasitoids, bacteria, fungus, and viruses regulate the population of insect pests under natural field condition. Biological control came into prominence in recent times owing to some spectacular success achieved in various parts of the world.

Biological control: Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition or Biological control involves use and manipulation of natural enemies by man.

Mass production technology:

Methodology for mass production of *Trichogramma chilonis* Ishii

A large number of Trichogramatids are reported as egg parasitoids of 200 insect species belonging to 70 families and 8 orders in diverse habitats of the world. In India about 26 *Trichogramma* species are recorded of which *T. chilonis, T. japonicum* and *T. achaea* etc. are widely distributed and are key mortality factors for many crop pest. These parasitoids attack eggs of many lepidopterous pest such as *Chilo* spp., *Scirpophaga excerptalis, Scirpophaga incertulas, Helicoverpa armigera, Agrotis* spp. *Pectinophora incertulas, Earias* spp., *Chilo partellus* etc. The Trichogramatids are minute parasitic wasps measuring 0.40 to 0.70 mm in length. It completes its developments in about 8-10 days. For mass production of Trichogramatids, rice moth, *Corcyra cephalonica* is used as laboratory host in India. However, in many European countries, Angoumois grain moth, *Sitotroga cerealella* is used as factitious host for its mass production.

Mass production of *Corcyra cephalonica* (Stainton)*:*

Materials required: Round iron or galvanized trays or rectangular wooden trays, broken grains for sorghum or maize, yeast powder, muslin cloth, oviposition cage provided with an inlet to introduce the moths and the bottom fitted with 40 mesh wire net, moth collecting glass tubes with funnel mouth, plastic tube, wooden racks, petri dishes, oven, honey solution, etc.

Methodology: Broken sorghum or maize grains are first sterilized at 70^0C for 2 hours in a hot air oven. Thereafter, the same grain should be conditioned before used. The sterilized grains are mixed with dried yeast powder @ 2 g/kg and 2.5 kg grains are kept in each tray. One cc eggs of *Corcyra* are sprinkled in each tray and kept for development. The tray are covered with a thick cloth or kept open in a low roofed rearing room. After emergence larvae feed on the grains and pupate inside the tray itself. The moth emergence starts from 30^{th} day onwards. The moths are collected daily and in oviposition cages for deposition. The moths lay most of the eggs within 3 days after emergence. The eggs are collected from the oviposition cages early in the morning and are used for the multiplication of *Trichogramma.*

Mass production of *Trichogramma chilonis* Ishii

Materials required: Glass jar/plastic bottles for keeping (exposed/parasitized) egg cards, egg cards, petri dishes, measuring cylinder, sieves, plastic trays, microscope, UV chamber, gum, camel hair brush, etc.

Methodology: The *Corcyra* eggs are obtained by confirming the moths in an oviposition cage. The eggs collected are passed through 25, 30 and 40 mesh sieves and run over a slop of paper to eliminate dust particles and scales of *Corcyra*. The eggs are exposed to ultra violet rays (15 Wt UV tube) for 30 minutes in UV chamber to kill the embryo. The sterilized egg are filled in plastic vial (9x5 cm) and closed with a lid of wire mesh (40mesh) for uniform spreading on cards pasted with a thin layer of dilute gum, *Acacia*. The eggs are glued to Trichocards of 15 x 10 cm size which are perforated to obtain 10 pieces (measuring 2.5 cm) leaving uncovered one end to facilitate stapling. The cards are placed in plastic bottles in which freshly emerged parasitoids are present or place the parasitized egg cards from which adult emergence is expected in a day. Host parasitoid ratio of 6:1 is to be maintained to avoid super parasitism. The jars/bottles are kept at 27± 2° C. Normally the eggs are exposed for parasitization for 24 to 48 hours. Parasitized eggs start turning black on 3rd day after parasitization. Normally 80 to 90 % parasitization is expected in healthy culture. Parasitized egg cards can be stored in refrigerator at 12-15 °C for 10 to 15 days. Prolonged storage will impair emergence, longevity and fecundity of the progeny. Only freshly laid eggs are preferred by *Trichogramma* female for oviposition.

Transport of egg cards:

The parasitized egg cards can be easily transported in the pupal stage (3 days after parasitization) by folding the cards and kept in polythene bags.

Release of *Trichogramma* in field:

The parasitoid may be released in the field as adults or the parasitized egg cards and it may be stapled to the underside of the leaves of crop plant by keeping eggs side on ground direction. The egg card can also be kept in plastic release boxes fitted with wire mesh at the bottom for adult emergence. The boxes may be either fixed on wooden poles or hung on host plant. The trichocards may be cut in to pieces through markings and hanged under plastic cup tied in inverted manner below plant twig.

Precautions: It is advisable to observe the following precautions during packaging and release of *Trichogramma* for better results. Trichocards should be packed keeping the surface with the parasitized eggs on the inner side. Emergence date should be specified on cards for the guidance of the end user. Cut pieces of Trichocards should be stapled on the inner side of leaf to avoid direct sunlight. Card pieces should be stapled in morning hours just before emergence to avoid predation. If adults of *Trichogramma* are to be released, the farmers should open the jar containing adult trichogrammatids and go on tapping the jar till all the adults fly out while walking in the field. Refrain from using pesticides for a week in the field where *Trichogramma* are released. If need arises use botanical or selective/safer insecticides.

Methodology for mass production of *Chrysoperla zastrowi sillemi*:

Sucking pests cause serious losses to many field, plantation and horticultural crops. Green lace wing (Aphid lion), *Chrysoperla zastrowi sillemi* is a potent predator of many sucking pests. The mass production technique of a predator is given below:

Materials required: *Corcyra cephalonica* rearing unit for the egg production, nucleus culture of *Chrysoperla spp.,* rearing trays, plastic jars, Slotted angle iron racks, working tables, weighing balance, scisors, brushes, cotton wool, forceps, tissue paper, brown paper separators, Foam sheet, sponge, acrylic sheet, Fructose, protinex, honey, yeast, castor, pollen etc.

Methodology: Steps involved in mass rearing of *Chrysoperla zastrowi sillemi*

- Conceal 200 pairs of adults in oviposition case, measuring 75 x 30 x 30 cm. The sides of the cage are lined with smooth nylon wire mesh (not preferred for egg laying) and the sliding top cover is fitted with black cloth for obtaining eggs. To prevent damage to the eggs, the top is slided over a comb fitted on both the sides of the cage. The sliding top cover is replaced on alternate days starting from 4 - day onwards. The oviposition cage is kept for 30 days and the dead adults are removed every alternate day.
- The adults in oviposition cage are fed on alternate days on cotton wool swabs soaked with the ingredients in a proper way *viz*., Drinking water, Honey 50% solution, Protinex mixture (equal quantity of protinex + fructose + powdered yeast dissolved in small quantity of water). Two swab of each of the three liquid should be hanged in case with the help of thread and thin iron wire. If sometime such case is not available, the emerged adults may be kept in dessicators or plastic jar containing honey solution soaked cotton wicks and closed with black cloth. Keep in side cotton leaves or tissue paper or brown paper or black paper for oviposition.
- One day old eggs (Egg chorion gets hardened) are dislodged from the black cloth top cover of oviposition cage by gently moving a piece of sponge. Thus, eggs collected can be used for further multiplication.
- Since the larvae of chrysopids are cannibalistic, rear them individually in plastic louvers/vials or in hexagonal cells. Place a foam sheet of the convenient size in the plastic rearing tray. Then, put the paper separators having hexagonal cells on the foam. Sprinkle about 300 to 400 *Corcyra* eggs (already inactivated by exposure to 15 W UV light for an hour) in each hexagonal cell. Introduce 3 day old 1-2 Chrysopid eggs / hexagonal cell. The covered may be secured with the help of lid of the tray. Small opening at the centre of the lid should be provided with wire mesh for aeration.

Utilization for field release and dose: Normally Chrysopids are released in the fields in its 1st instar larval stage against different field crops at the rate of 50,000 to 1,00,000 larvae/ha or 10-20 larvae/fruit plants. Depending upon pest saturations, 2 releases at fortnightly interval are recommended for control of following sucking pests and early instar larvae of Lepidopteran pests.

Methods of release: The *Chrysopid* larvae can be released in the field by;

- Broadcasting larvae with saw dust on thick crop canopy.
- Stapling of Chrysopa card as per the methodology suggested for Trichocards.
- Dropping 1 or 2 larvae per plant on leaves or 10-20 larvae/tree placing corrugated paper strip on the plants/trees or the eggs mixed in saw dust are dropped on crop canopy.

Precautions: Rear the grub stage individually to avoid cannibalism. Release should be made in early morning hrs to settle larvae on crop canopy. Avoid to release freshly laid eggs as they may be parasitized or predated in more numbers in the field. Do not use pesticides in the field where the predators are released: otherwise use selective/safer pesticides after or before 10-15 days of release following strip or staggered spray method.

Organizing exposure visit to research/training institutes of bio-agents:

Exposure Visit is useful to gain the knowledge and experience of the work culture and provides an agro-industrial exposure to the students for developing their career in the Agro based industries. It is a method by which a group gets together for the purpose of seeing an improved performance or result of practice in actual situations. This requires the group to move out of the area for a considerable period with a pre-decided programme. A field visit will be organized and the students will record their observations.

6. Place of visit:
7. Purpose of visit:
8. Which are the important equipments that you have observed during the visit?
9. Which problems of research/training institutes are identified in the field visit?
10. What interesting information is noted during visit?

Answer the following questions

1. Write the mass production technology of the factitious host?
2. Mass production technology of *Trichogramma chilonis*.
3. Which are the precautions are to be taken during the Trichogramma handling?
4. Mass production technology of *Chrysoperla zastrowi sillemi.*
5. Which are the precautions are to be taken during the *Chrysoperla* handling?
6. Describe the general cares for transportation bio-agent to the new locality.
7. Which stage of the host is parasitized by *Trichogramma?*
8. Which laboratory hosts are used for mass production of *Trichogramma?*
9. Approximately how many eggs of *Corcyra* are there in one cc?
10. How many eggs can be glued on one Trichocard?
11. What should be the ratio of host eggs glued on card and *Trichogramma* during exposure for effective parasitization?
12. How much old *Corcyra* eggs can be used for parasitisation by *Trichogramma?*
13. Why *Corcyra* eggs are exposed to UV rays before parasitisation?
14. Which factors are responsible for effectiveness of Trichogrammatids?
15. What are the limiting factors for the success of Trichogrammatids in biological control?
16. Give the comments about exposure visit to research/training institutes.

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EXERCISE NO. 12

IDENTIFICATION OF OTHER IMPORTANT POLLINATORS, WEED KILLERS AND SCAVENGERS

Date:

Objectives:

1. To study the other important pollinators, weed killers and scavengers.

I. Pollinators:

A pollinator is the biotic agent (vector) that moves pollen from the male flower to the female flower to accomplish fertilization.

Role of pollinators:

- Pollination refers to the transfer of anther to stigma in flowering plants for sexual reproduction.
- Insects and in cross-pollination in fruits, vegetables, ornamentals, cotton, tobacco, sunflower and many other crops.
- Insect pollination helps in uniform seed set, improvement in quality and increase in crop yield.

Entomophily refers to cross pollination aided by insects

Pollination	Type of insects
Melitophily	Bees
Cantharophily	Beetles
Cantharophily	Syrphid and Bombylid flies
Sphigophily	Hawk moths
Phalaeophily	Small moths
Sphigophily	Hawk moths

1. Honeybees as pollinators

- All bee species aid in pollination
- Value of honey bees in pollination is 15 -20 time higher than that of the honey and wax it produces.

Crop	Per cent increase in yield due to bee pollination
Mustard	43 %
Sunflower	32-48 %
Cotton	17-19 %
Lucerne	112 %
Onion	93 %
Apple	44 %
Cardamom	21-37 %

2. Hoverflies *Syrhus sp*. (Syrphidae: Diptera)

- Brightly coloured flies
- Body is striped or banded with yellow or blue
- Resemble bees and wasps
- Larval stage predatory, adults are pollinators
- Crops pollinated – carrot, cotton, pulses

3. Carpenter bee, *Xylocopa sp*. (Xylocopinae: Anthophoridae)

- Robust dark bluish bees with hairy body
- Dorsum of abdomen bare, pollen basket absent
- Adults are good pollinators
- Construct galleries in wood and store honey and pollen

4. **Digger bees, *Anthophora sp*. (Anthophoridae: Hymenoptera)**
- Stout, hairy, pollen collecting bees
- Abdomen with black and blue bands

5. **Fig wasp, *Blastophaga psenes* (Agaonitae : hymenoptea)**
- Fig is pollinated by fig wasp only.
- There is no other mode of pollination.
- There are two types of fig Caprifig and Symrna fig.

Capri fig	**Symrna fig**
• It is a wild type of fig-not edible • Has both male and female flowers • Pollen is produced in plenty • Natural host of fig wasp	• It is the cultivated type of edible fig • It has only female flowers • Pollen not produced • Not the natural host of fig wasp

In fig wasps males are wingless, present in Capri fig and females winged. Female wasp lays eggs in Capri fig, larvae develops in galls in the base of the flowers. Male mates with female even when the female is inside gall. Mated female wasp emerges out of flower (Capri fig) with lot of pollen dusted around its body. The female fig wasp enters Smyrna fig with lot of pollen and deposits it on the stigma. But it cannot oviposit in the ovary of symrna fig which is deep seated. It again moves to Capri fig for egg laying. In this process Smyrna fig is pollinated. Capri fig will be planted next to Smyrna fig to aid in pollination.

6. **Oil palm pollinating weevil: *Elaeidobius kamerunicus* (Curculionidae: Coleptera)**
- Aid in increasing oil palm bunch weight by 35 per cent and oil content by 20 per cent.

7. **Other Pollinators**
- Butterflies (e.g. *Deilaphila* spp.) and moths (*Acherontia* spp.)
- Ants, flies, stingless bees, beetles, etc.

II. Weed Killers:

Quite many insects feed upon unwanted weeds just the same manner they do with cultivated crops. Because they damage the noxious and menacing weeds, these insects are considered helpful or friendly to man. In many cases the occurrence of these insects has contributed much towards eradication of the weed or at least keeping it in check.

What is a weed?

A weed is a plant in the wrong place. They cause losses in many ways like (a) Yield loss due to competition (b) Increased cost of cultivation (c) Direct injury to man, livestock or livestock products (d) Depreciation of watershed and wild life values (e) Serving as alternative hosts for insect pests or plant pathogens.

Insects as agents for weed control:

From the year 1902 when eight species of insects were introduced into Hawai from Mexico for the control of *Lantana camera*, insects have been principal agents used in biological control of weeds. These insects feed on various parts of the weed plants and destroy them. Important groups of insects which have been successfully used for weed control are;

Lepidoptera	Phycitidae, Trotricidae
Homoptera	Coccidae
Hemiptera	Coreidae, Tingidae
Coleoptera	Cerambycidae,Chrysomelidae, Buprestidae, Cuurculiionidae, Galeuricidae
Diptera	Agromyzidae, Trypetidae

Action on weeds:

Insects often destroy weeds through direct destruction of vital parts. Ex: Action of *Cactoblastic cactorum* on Opuntia. The weed may die quickly or die during the next season.

Insects also attack weeds indirectly through Creating favorableness to infection by plant pathogens (b) Affecting the competitive advantage of the weed.

Desirable attributes of a weed killer:

1. It should not itself be a pest of cultivated plants (as *Orthezia insignis*) and should not even at a later date turn to attack useful crops, which is often the case with weed killing insects.
2. It should be effective in damaging and controlling the weeds.
3. It should preferably be a borer or internal feeder of the weed. Leaf feeders have also been found to be equally effective in checking weeds.
4. If should be able to multiply in good number without being affected very much by parasitoids and predators.

Examples of biological control of weeds with insects:

1. **Lantana weed, *Lantana camera*:** It is a perennial shrub, native of Central America; is used extensively throughout the world as an ornamental plant. *Ophiomyia lantanae* was introduced into India from Hawaii for the control of Lantana. But an introduced coccid (scale insect) *Orthezia insignis* besides its failure to effectively check the weed began to infest economic plants like citrus, coffee, cinchona and tomato.
2. **Prickly pear, *Opuntia*** spp**:** The prickly pear, *Opuntia inermis* (*O. stricta*) got accidentally introduced into that country by 1840. The cactus spread was so rapid that in the year 1925, 24 million hectares of cultivable land were rendered useless. Control of this weed by chemical and mechanical means was not feasible and was too costly. In 1925 the moth borer, *Cactoblastis cactorum* (Pyralidae: Lepidoptera) was introduced from Argentina and the plants were killed by damaging them into papery structures. Within few years the weed population was reduced to a very great extent that Opuntia was no more a problem.

In India, *Opuntia dilleni* was wrongly introduced in 1780 in the place of *O. cccinellfera* for the cultivation of the commercial cochineal insect *Dactylopius coccus* valued for its dye. The cactus got established and spread rapidly assuming a serious proportion as a noxious weed. *Dactylopius tomentosus* was introduced from Sri Lanka in 1926 and within two years the insect effected a striking control of *Opuntia dilleni* in about 1,00,000 acres.

3. **Crofton weed,** *Eupatorium adenophorum* in Nilgiris and Palani hills was controlled by introducing an exotic Tephritid fly, *Procecidochares utilis* from New Zealand.
4. **Water hyacinth,** *Eichhornia crassipes* was successfully controlled with *Neochetina eichhorniae*, *N.brunchi* and mite *Orthogalumna terebrantis* (Curculionidae) in Kerala and Karnataka.
5. **Water fern,** *Salvinia molesta* was successfully controlled with *Cryptobagus cingularis* (Curculionidae) in India.
6. **Siam weed,** *Chromolaena odorata* by release of *Parenchaetes pseudoinsulata* (Arctiidae) has been found promising in Kerala and Karnataka.
7. **Congress grass,** *Parthenium hysterophorus* (Carrot weed, white top) has been successfully controlled in Karnataka by Mexican beetle, *Zygogramma bicolorata* (Chrysomelidae).

III. Scavengers:

Insects which feed on dead and decaying plant and animal matter are called scavengers. Remove decomposing material and prevents health hazardConvert complex material into simple substances e.g. dung roller.

Rove beetles (Staphylinidae: Coleoptera)

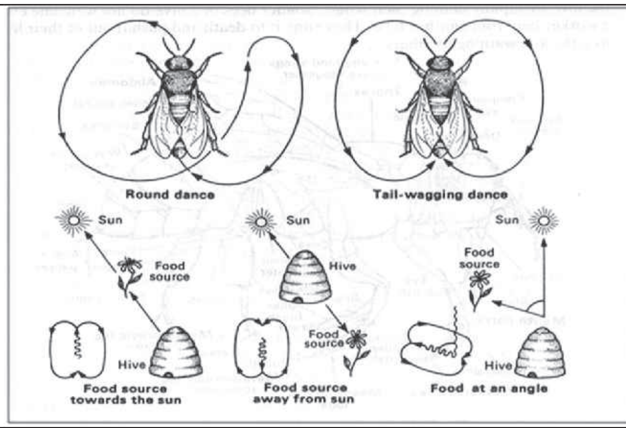
- Adults and larvae feed on decaying matter
- Chafer beetles (Scarabaeidae: Coleptera)
- Bark beetles (Tenebrionidae: Coleoptera)

- Nitidulids (Nitidulidae: Coleoptera)
- Water scavenger beetle (Hydrophilidae: Coleoptera)
- Daddy long legs (Tipulidae: Diptera)
- Muscid flies (Muscidae: Diptera)
- Termites (Isoptera)
- Ants (Hymenoptera) – live and feeds upon dead animal and decaying vegetation.

Answer the following questions:

1. What you understood by cross pollination?
2. Enlist the different types of entomophily with example.
3. Differentiate: Capri fig Vs Symrna fig
4. Enlist the different types of weed killers.
5. Which are the desirable attributes of a weed killer?
6. Give the examples of successful of biological control of weeds.
7. Enlist the different types of scavengers.

****



Bee comminication

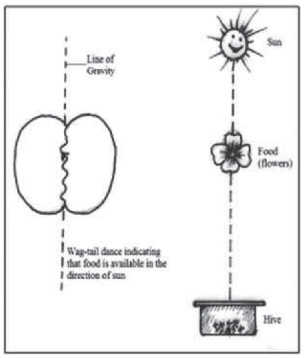


Fig. 1: Direction indication in wag-tail dance when food is in the direction of sun

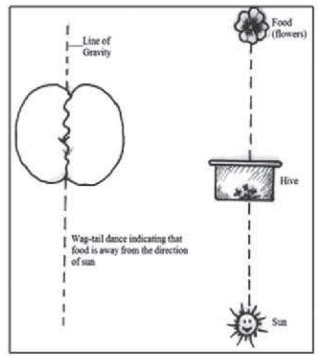


Fig. 2: Dance when food is away from direction of sun

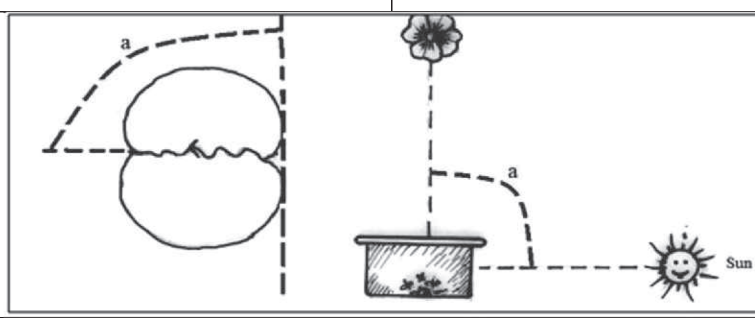


Fig. 3: If food is to the left of the sun, bee dances at an angle counterclockwise to the line of gravity

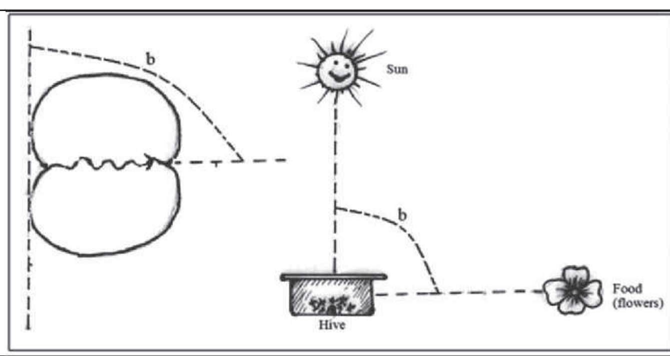
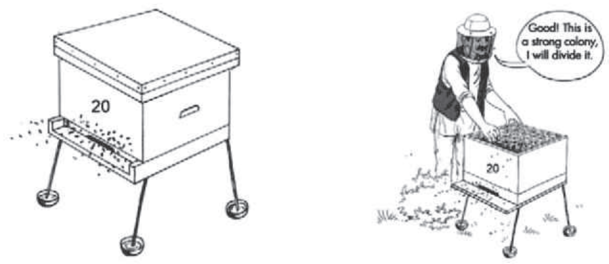


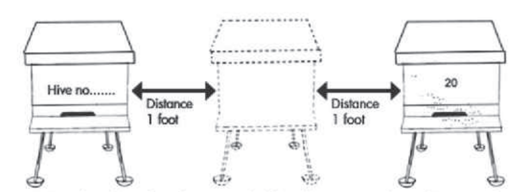
Fig. 4: If food is to the right of the sun, bee dances to the right of the line of gravity

Methods for colony division

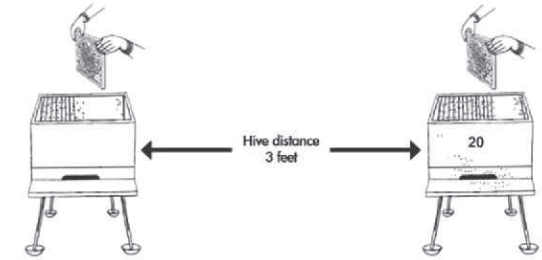


Step 1: Inspect the colonies

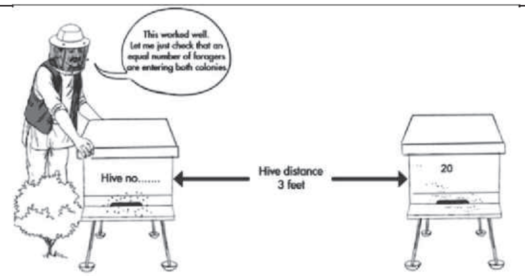
Step 2: Select the best mother colony



Step 3: Move the mother colony 1 ft (30 cm) to the left and place an empty hive 1 ft (30 cm) to the right of the previous mother colony position. The hives are a hive width plus 2 feet apart

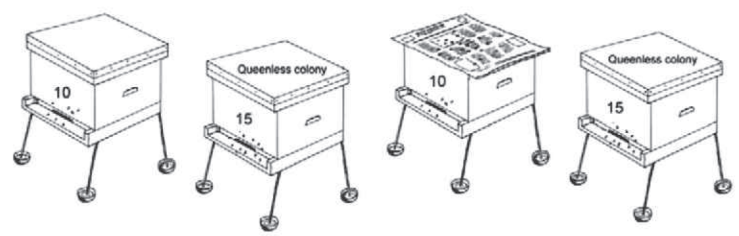


Step 4: Put 4 to 5 brood frames with the queen in the new hive



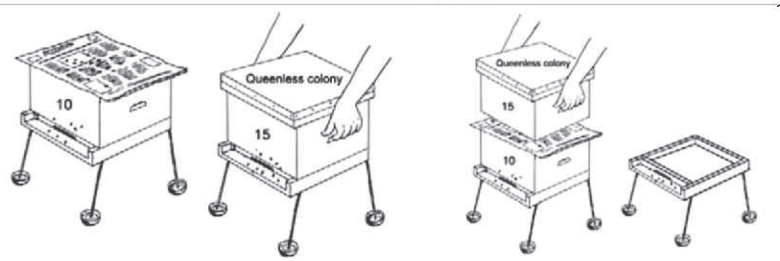
Step 5: Check the colony division is balanced and close the hives with the covers

Uniting honeybee colonies by newspaper method



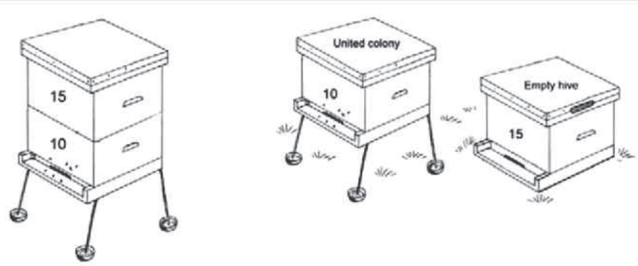
Step 1: Queen-right and queenless colonies moved close together

Step 2: Covers of queen-right colony removed and replaced with a sheet of perforated paper smeared with syrup or honey



Step 3: Queenless colony lifted from bottom board

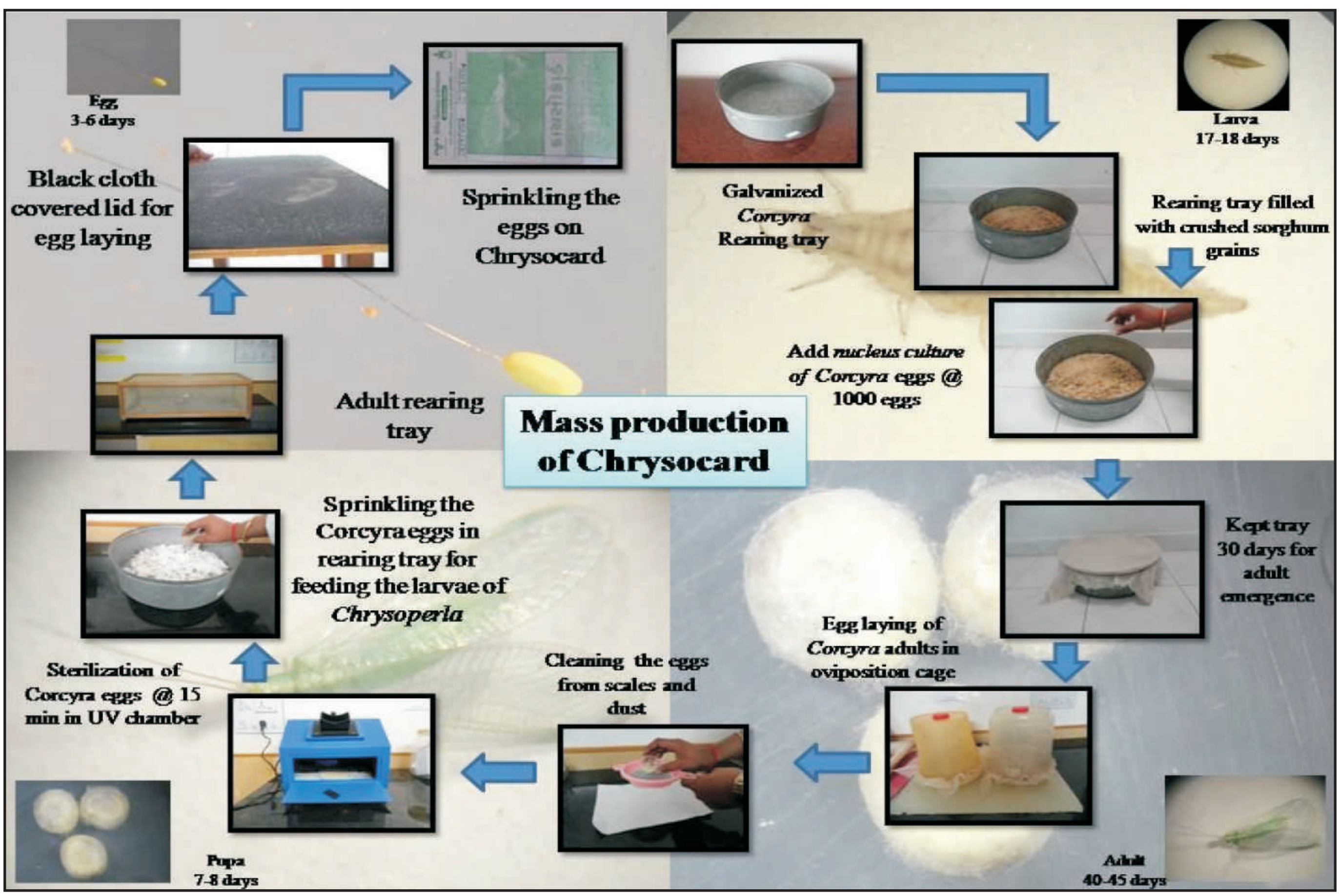
Step 4: Queenless colony placed on sheet of paper above queen-right colony

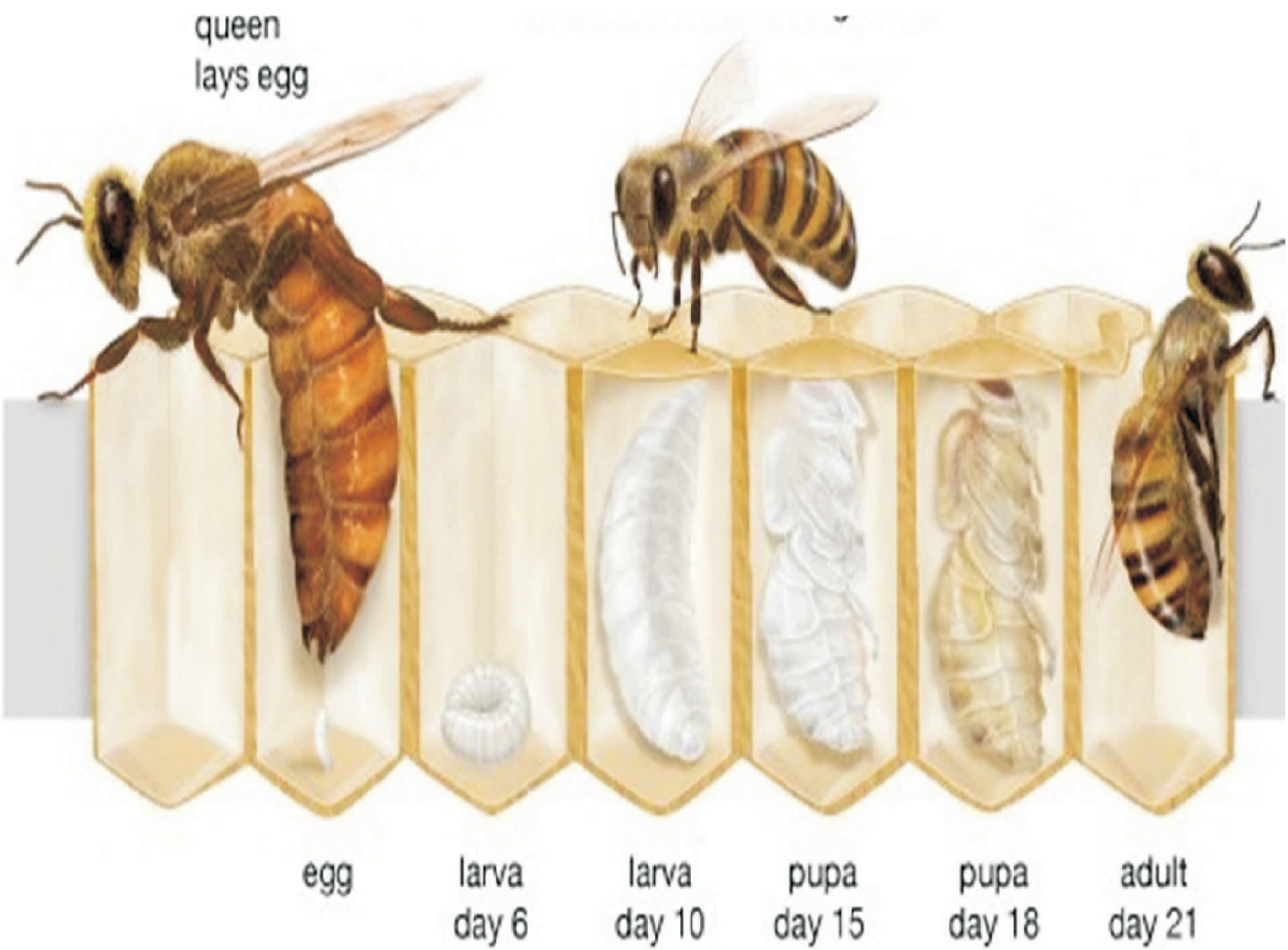


Step 5: Pheromones of colonies allowed to unite while bees chew the paper

Step 6: After 2 days bees and frames from upper chamber transferred to lower chamber and covers replaced on the united colony


Mass production of Trichocard
Galvanized *Corcyra* Rearing tray
Rearing tray filled with crushed sorghum grains
Add *nucleus culture of Corcyra* eggs @ 1000 eggs
Kept tray 30 days for adult emergence
Egg laying of *Corcyra* adults in oviposition cage
Cleaning the eggs from scales and dust
Sterilization of Corcyra eggs @ 15 min in UV chamber
Sprinkling of *Corcyra* eggs on Trichocard @ 1 cc/card
Kept fresh cards in jar (1:6) for parasitisation
Parasitization of card for 24 hrs and kept for adult emergence after 6-7 days
Stapling the individual stripes at under surface of leaf


Mass production of Chrysocard
Galvanized *Corcyra* Rearing tray
Rearing tray filled with crushed sorghum grains
Add *nucleus culture of Corcyra* eggs @ 1000 eggs
Kept tray 30 days for adult emergence
Egg laying of *Corcyra* adults in oviposition cage
Cleaning the eggs from scales and dust
Sterilization of Corcyra eggs @ 15 min in UV chamber
Sprinkling the Corcyra eggs in rearing tray for feeding the larvae of *Chrysoperla*
Adult rearing tray
Black cloth covered lid for egg laying
Sprinkling the eggs on Chrysocard
Egg
3-6 days
Larva
17-18 days
Pupa
7-8 days
Adult
40-45 days


queen
lays egg
egg
larva
day 6
larva
day 10
pupa
day 15
pupa
day 18
adult
day 21

COLLEGE OF AGRICULTURE,
NAVSARI AGRICULTURAL UNIVERSITY,
WAGHAI, GUJARAT

PRACTICAL MANUAL

AGRON: 4.4

Crop Production Technology- II (*Rabi* crops)

FOUTRH SEMESTER, B.Sc. (Hons.) Agri.

PREPARED BY

DR. Vikas. R. Naik
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Dr. A. P. Patel
Associate Professor

Dr. R. R. Pisal
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CERTIFICATE

This is to certify that Mr. /Miss. ________________________________

Roll. No.____________ Reg. No. ______________________________

studying in fourth Semester, B.Sc. (Hons.) Agriculture has satisfactory carried out ____________ practical exercises out of _________ in the subject of Agron. 4.4 (**Crop Production Technology- II (*Rabi* crops)**) at College of Agriculture, NAU, Waghai during the year _____________________.

Course Teacher

Professor & Head

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7	Numerical exercises on fertilizer requirement			
8	Numerical exercises on plant population			

I. Identification of crops and seeds

Wheat

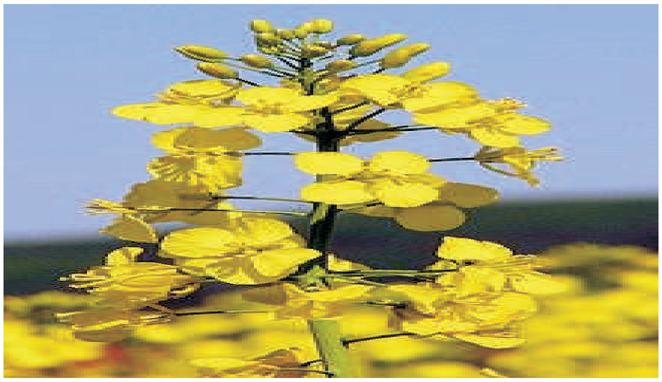
Botanical name	**Family**	**Origin**
Triticumaestivum L., *Triticumduram* desf.	Gramineae	South Western Asia

Barley

Botanical name	Family	Origin
Hordeumvulgare L.	Gramineae	Asia and Ethiopia

Rape seed

Botanical name	Family	Origin
Brassica campestris (Rapeseed)	Cruciferae	Eastern Afghanistan and adjoining parts of India and Pakistan



Mustard

Botanical name	Family	Origin
Brassica juncea (Mustard)	Cruciferae	China

Linseed

Botanical name	Family	Origin
Linumusitatissimum L.	Linaceae	Mediterranean region (including Egypt, Algeria, Spain, Italy and Greece).

Sunflower

Botanical name	Family	Origin
Helianthus annus L.	Compositae	USSR

Botanical name	Family	Origin
Saccharumofficinarum L.	Gramineae	India

Mint

Botanical name	*Menthaarvensis, Menthacitrita, Menthalongifolia*
Family	Lamiaceae
Origin	Europe and Asia

II. Methods of Sowing: Wheat

Wheat is sown by five methods:

1. **Broadcasting:** In this method the seeds are broadcast and then worked in by harrowing in order to cover them. However, the seeds are not uniformly distributed in the field. This method of sowing is very insufficient and should not be encouraged. Germination of broadcast seeds is relatively poor and the plant stand is often irregular. Wastage of seed also results because most of the seed is left on the surface where they cannot germinate and may, therefore, be picked up and eaten by birds.

2. **Behind Local Plough:** A majority of farmers uses this method. This method consists of dropping the seeds by hand into the furrows that have been opened with local plough. When seed is dropped in furrows by hand, it is called 'kera' method and when it is dropped through a *Pora* or *Nai*or *Hazara*a special attachment with local plough it is called 'Pora' method. In this method seeds are dropped of at a depth of 5-6 centimeters and germination is satisfactory.

3. **Drilling:** In this method seed is sown by seed drill or ferti-seed drill. With the help of this implement seed drop at depth and results in uniform germination and regular stand. Seed bed should be fine and well leveled free from clods and weeds for the use of seed drill or ferti-seed drill. Seed drills are easily available in the market. They may be either bullock driven or tractor driven. Ferti-seed drill should be used wherever possible to ensure uniform depth of sowing, proper placement of fertilizers and good germination.

4. **Dibbling:**This method is used in case where supply of seed is limited. Sowing is done with the help of a small implement known as 'Dibbler'. It is a wooden or iron frame with pegs. The frame is pressed in the field and lifted and then one or two seeds are dropped by hand in each of the hole. It is not a common method because it is a very time consuming process.

5. **Zero tillage technique:**This new method is used in Rice-Wheat cropping system where showing of wheat is delayed beyond 25 November. Sowing is delayed due to multiple reasons, viz. preparation of field, uncertain rainfall and rice harvesting with traditional method. Out of these, the field preparation is one of the most important reasons, which causes delay in wheat sowing. Puddling in transplanted rice creates a hard pan in the field. After harvesting of rice crop , field requires at least 6-8 tillage operations in ploughing and harrowing for sowing of wheat, in which generally 10-15 days are required for proper field preparation. Yield of wheat decreases at the rate of 30 kg per hectare per day after 25 November sowing.

A Zero-till-ferti-seed-drill machine has been developed at G.B.Pant University of Agriculture and Technology, Pantnagar by which direct sowing of wheat is done in Rice field without ploughing. This helps advancing the sowing of wheat as the time required for field preparation is saved. Zero-tillage can be adopted with following precautions

- At the time of sowing there should be proper moisture in the field.
- Rice should be harvested near the ground and the left over stubble should not be more than 15 cm in height and field should be free from weeds.
- At the time of sowing the seed-drill should be lifted up or lower down very slowly to avoid clocking of furrow opener by soil, otherwise seeds and fertilizer will not drill in the furrow.
- Seed should be treated with vitavax or Bavistin at the rate of 2.5 g/kg of wheat seed. Seed rate should be 140-150 kg/ha (20-25% higher).
- Sowing depth should be maintained about 5-6 cm.
- Light planker may be used behind the zero-tillage machine.
- After sowing by Zero-till-seed-drill, other package of practices remain the same as in other methods.

The Zero-till-ferti-seed-drill has knife type lines in place of shovel type and is suitable for sowing under Zero-tillage conditions as well as conventional field preparation. The lines are fitted at a distance of 20 centimeters and have a provision to shift by 2.5 centimeters on either side. The machine is fitted with 2 boxes, one for seed and the other one for the fertilizer. On each box, lever is provided along with locking bolts and marking to get known quantity per hectare. Seedling depth can be manipulated by adjusting two side depth wheels with the help of screw bolts. Front driving wheel is provided with a groove to adjust as per requirement. A wooden platform is provided to keep a man to monitor the chocking of seed and fertilizer tube. Zero-tillage machines are provided with two lower link pins and a lift patti to attach the machine with tractor.

Broadcasting

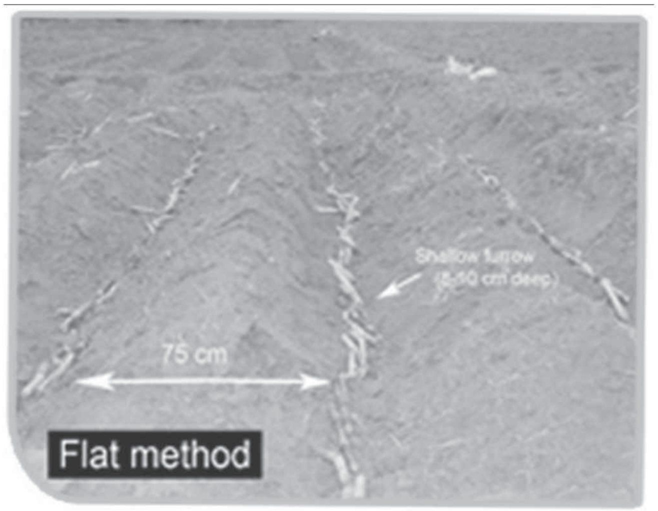
Dibbling

Zero tillage

Drill method

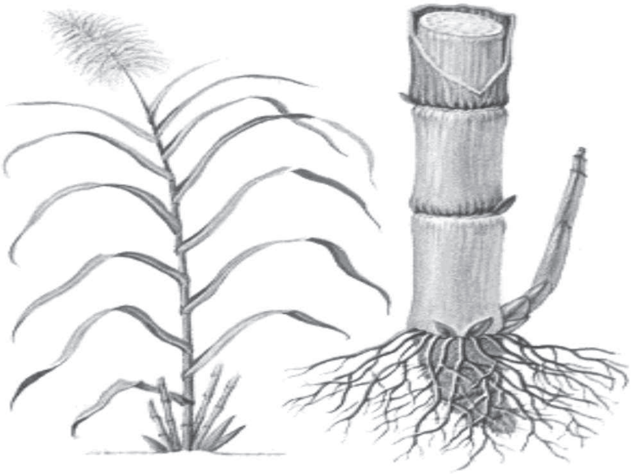
B) Flat Bed Method:

1 Flat bed method of sugarcane planting is followed in North Indian states like U.P.; Bihar etc.
2. The land is ploughed, harrowed, levelled and flat beds are prepared.
3. Cane sets are laid down in the flat beds end to end in rows.
4. 60 to 90 cm. distance is kept between two rows depending upon soil type.
5. They are pressed into soil with hand or feet to a depth 2.5 to 5 cm and covered with soil.
6. At the time of planting care should be take that buds should face on the sides otherwise lower buds cannot germinate.
7. This method is followed where there is abundant moisture.
8. Earthing up operation is done in rainy season.



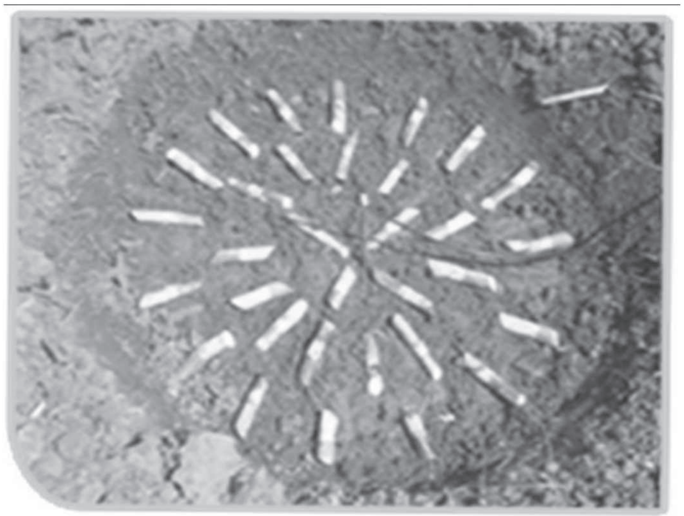
C) Rayungan Method:

1. Rayungan method is followed for adsali sugarcane planting at river side's fields in heavy rainfall areas of Kolhapur district.
2. In these areas usually cane fields get flooded during rainy season which affects on germination.
3. In such cases set cannot be planted directly in main field.
4. Single bud sets are planted vertically in nurseries which are prepared high lying area of the farm in the month of June – July.
5. After six weeks the sprouted sets are transplanted in the main field when the danger of flooding is over.



D) Trench or Jawa Method:

1. This method is practiced in Jawa and Mauritius.
2. Trenches are made about 90 to 120 cm. apart and 22 to 30 cm. deep.
3. The soil at bottom is loosened and mixed with manures.
4. The sets are planted in the middle of the trenches and covered with soil.
5. Irrigation is given after completion of planting.
6. This method produces large clumps of cane which do not lodge when tied together.
7. The damage from wild animals is also less.
8. This method has not given good results with Indian varieties hence not followed in India.



IV.Seed treatment of different *rabi* Crops.

Defination: Seed treatment refers to the application of fungicide, insecticide, or a combination of both, to seeds before sowing for various purposes to control insects, pests, diseases, improving germination, atmospheric nitrogen fixation and inducing the initial root growth of crop.

Benefits:

1. Prevent spread of plant diseases.
2. Protect seed from seed rot and seedling blights.
3. Improve germination.
4. Provide protection from storage insects.
5. Control soil insects and soil borne diseases.
6. Increase the crop yield.

Seed treatment for different field crops

Sugarcane:

- For the control of Mealy bug and scale insects: Setts should be dipped in the 0.1 % solution of Melathion for five minutes before use
- For seed born and soil born diseases: Setts should be dipped in to 0.5 % Aretan or Amisan solution for five minutes before planting
- For better germination: **A**. Setts should be dipped in 0.5 kg of quick lime in 200 liters of water for 12 hours. **B**. Hormones treatment with Naphthalene Acetic Acid (NAA) or Indole Acetic Acid (IAA) or Gibberlic Acid (GA) in 10 ppm solution

Chicory:

- For uniform distribution of seeds at sowing seed should be mixed with fine sand or oilseed cake or FYM

Wheat:

- For root rot and seedling rot: Agrosan/Ceresan @ 3 gm/kg seeds
- For termite: Endosulphan @ 700 ml for 100 kg seeds or Chlorpyriphos 450 ml for 100 kg seeds in 5 lit water

Barley Cumin & Fennel

- For seed borne diseases: Agrosan/Cerasan @ 3 gm/kg of seeds
- For good germination: Soak the seeds in to water for 8 hrs, dry under shade before sowing
- For Blight: Treat the seeds with Agrosan/Ceresan/Thirum @ 3 gm/kg of seeds

Pulses:

- Seed borne and fungal diseases: Agrosan/Cerasan/Captan @ 3 gm/kg of seeds
- For atmospheric nitrogen fixation: Seeds inoculation with *Rhizobium* and *PSB* @ one packet (250 gm/8-10 kg seeds of each culture

V. Effect of sowing depth and methods on germination of Crops

- **Type of sowing**

1. **Dry sowing:**

Dry sowing is adopted in black soils where sowing operations are difficult to carry out once rains commence. Field is prepared with summer rains and seeds are sown in dry soil around seven to ten days before the anticipated receipts of sowing rains. The seeds germinate after the receipts of rains. By this method, rainfall is effectively utilized.

2. **Wet sowing:**

Wet sowing is the most common method of sowing crops. The minimum amount of rainfall necessary for taking up sowing is 20 mm. Two or three days after soaking rains, sowing can be taken and continued for 2 or 3 days. Certain amount of moisture is wasted during the period between receipt of rainfall and sowing.

- **Method of sowing**

1. **Broad casting**

This is an oldest method. This method is suitable for close planted crop which don not require a specific geographic area. Crop plants not require special type of cultural practices e.g., earthing up or picking etc. may be sown by broadcasting. This method is followed in the crop having short life period. Seeds are spread or scatter by hands over the field and covered with the help of weeden rake or light plank. e.g. Cumin, Isabgul, Coriander, Rajgira, Berseem etc.

2. **Drilling**:

Drilling ia practice of dropping seeds in furrows by a mechanical device at a regular distance between rows. Seeds are drilled in parallel line, distribution of seeds is regulated by realizing seeds in to bowl by the hand. For covering the seeds light planking is done by samar e.g. Upland rice, wheat, bajara, Harley, mustard, cowpea, green gram, etc.

3. **Dibbling:**

Putting a seed or few seeds in a hole or pit or pocket, made predetermined spacing and depth with a dibbler or very often by hand. This method is suitable for wide space crops requiring a specific geometric area for their canopy development or cultural practices. First, all lines are mark vertically and horizontally with the help of marker at a particular distances and at each cross, seeds are dibbled with the help of dibbler by labour. Then seeds are covered with soil. e.g., Cotton, Castor, Tur, etc.

4. Planting:

Placing of plant part (vegetative propagates) in soil called planting. The vegetative propagates are planted directly on the field should be good health, vigor, age, age of growth and desirable number of readily sprouting bud e.g. Tubers-potato, Rhizomes-ginger and turmeric, Bunches-onion, Cloves-garlic Vine set- sweet potato, Setts-sugarcane, Rooted slips-Napier grass, Blue penic grass.

5. Transplanting

Transplanting is a removal of an actively growing plant from one place and planting with in another for further growth and production. In this method seeds are not directly sown in the field but seeds are sown in the nursery with proper care. After proper growth (generally four weeks), seedling are uprooted and transplanted in well prepared main field. This method is useful for raising the crops which have small size seeds and require more care in the initial dstage. E.g. Seedling- Rice, Tobacco, Tomato, Brinjal, Sapling: Subabool, Stecklings -Sugar beet.

- **Depth of sowing**

Depth of sowing governed by two factors viz.,

1. Size of the seed
2. Soil moisture content

Uneven depth of sowing results in uneven crop stand. Plants will be of different sizes and ages and finally harvesting is a problem as there is no uniformity in maturity. Shallow or deep sowing result in low plant population because all seed do not germinate. Therefore, it is essential to sow the crop at optimum depth for obtaining good stand of crop. Crops with bigger size seeds like Groundnut, Castor, Sunflower etc, can be sown even up to the depth of 6 cm. Whereas, small sized seeds like tobacco, sesamum, bajara, mustard have to be sown as shallow as possible. If the seeds are son to shallow, the surface soil dry quickly and germination may not occur due to the lake of moisture, Therefore, small sized seeds which are sown shallow should be watered frequently to ensure good emergence of crop. If the small seeds of crop sown deep in the soil, the seed reserved food may be inadequate to put forth long coleoptiles for emergence. Even if the seedling emerges, it is to week to survive as an autotroph. For better germination, the soil should have sufficient moisture in the surface layer. Crop grown in rabi are sown deeper than kharif crop, because in rabi surface soil have insufficient moisture for germination. The thumb rule is to sow seeds to a depth approximately 3 to 4 times their diameter. The optimum depth of sowing for most of the field crops ranges between 3 to 5 cm. Shallow depth of planting of 2 to 3 cm is follow for small seeds like bajara, sesamum, mustard. Very small seeds like tobacco are paced at depth of 1 cm. This is generally done by broadcasting on soil surface and mixing them by racking.

VII. Numerical on plant population

Plant population of a crop in an area decides the yield. The row spacing and plant to plant spacing are used to calculate plant population which varies with the crop.

In each case plant population is calculated as described below

Case I: Row to row and plant to plant spacing is definite

e.g. maize, rice cotton, mustard, sunflower, etc.

$$\text{Plant population} = \frac{A\ x\ 100\ x\ 100}{R\ x\ P}$$

A= Area (m^2), R= Row spacing (cm) and P= Plant spacing (cm)

Case II: Row to row spacing is definite but plant to plant spacing is not definite

$$Plant\ population = \frac{N\ x\ A\ x\ 100\ x\ 100}{R\ x\ L}$$

A= Area (m^2), R= Row spacing (cm), N= Number of plant in row and L= Row length (cm)

Case III: Crop sown by broadcasting method

$$Plant\ population = \frac{N\ x\ A\ x\ 100\ x\ 100}{W\ x\ L}$$

A= Area (m^2), L= length (cm), N= Number of plant in Quadrate and W= Width (cm)

Case IV: Crop is sown in intercropping system in replacement series

In such cases, first determine plant population for sole crop in given area then calculate it according to its sown proportion

Suppose, P and Q crops are sown in a:b ratio.

Plant population of P crop in A m^2 area = (Sole population of P in A^2 area) x a/(a+b)

Plant population of Q crop in Am^2 area=(Sole population of Q in A^2 area) x a/(a+b)

Case V: Intercropping additive series

In such case there is no change in plant population of main crop. If ‘n’ number of row of intercrop are sown in‘d’ cm inter row space of main crop, then row distance of intercrop= d/n.

Now, calculate plant population of intercrop as in Case I or Case II by row spacing=d/2

Exercise

1.	Calculate the plant population of maize in 6000 m^2 area, if sown at spacing of 60cm x25 cm
2.	What would be plant population of maize in 1 ha area, if crop geometry is 60cm x 25cm
3.	Wheat crop is sown at row spacing of 22 cm. What would be plant population in 1 ha area, if there are 12 plants in 20 cm row length.
4.	Calculate the plant population of pea in 4000 m^2 area. If sown at row spacing of 30cm and 1 m row length has 20 plants.
5.	At harvest, numbers of millable canes (NMC) in 5 m row length were 45. Calculate NMC in 1 ha area if sugarcane was planted at row spacing of 90 cm.
6.	A quadrate having length 1 m and width 50 cm is used for sampling in broadcast sown wheat crop. Calculate plant population in 4000 m^2 area, if there are 60 plants in sampling area.
7.	Rice crop grown by broadcasting method in a field which size is 50m x 40m. What would be plant population in the field, if quadrate (0.5m side each) contains 40 plants.
8.	Maize and sunflower are grown in intercropping (replacement series) ratio of 2:1 in a field of 5000 m^2 area. Calculate the plant population of both the crops if planting geometry is 60cm x 25cm in each crop
9.	Maize is grown at planting geometry of 60cm x 25cm. Two lines of urdbean are sown uniformly between 2 lines of maize in additive manner. The spacing of two lines of urdbean is 30cm and plant to plant distance is 5 cm. Calculate the plant population of both crops in 1 ha area.

VIII. Numerical exercises on fertilizer requirement

Case I: Fertilizer contains only one nutrient

$$\text{Amount of fertilizer(kg/ha)} = \frac{\text{Rate of nutrient application (kg/ha)}}{\text{Nutrient content in fertilizer (\%)}} \times 100$$

Case II: Fertilizer containing two or more nutrients

First calculate the amount of fertilizer for the nutrient which is applied in lower amount by using formula as given in case I

Then calculate the amount of other nutrient received from this fertilizer amount from the following formula:

$$Amount\ of\ nurient(kg) = Amountof\ fertilizer\ (kg) \times \frac{Nutrient\ content\ (\%)}{100}$$

Case III: Both FYM/Compost and fertilizers are applied

First calculate the amount of FYM/compost with respect to one of the any nutrient as given in Case I

Then calculate the amount of other nutrients received from the FYM/compost amount as given in Case II

Now take the difference between amount of nutrient to be applied and amount of nutrient received from FYM/compost

This difference is fulfilled by fertilizer application by using formulas given in Case I.

Exercise

1.	What will be the quantity of urea (46 %) for one ha area if 150 kg/ha is to be applied
2.	Calculate the amount of urea (46 %) for 4000 m^2 area if nitrogen application rate is 120 kg/ha
3.	The recommended doses of N, P_2O_5 and K_2O for wheat are 150, 60 and 40 kh/ha, respectively. Calculate the quantity of urea (40 % N), single super phosphate (16 % P_2O_5) and MoP (60 % K_2O) to supply these nutrients in 3 ha area.
4.	Calculate the amount of urea (46 % N), DAP (18 % N and 46 % P_2O_5) and MoP (60 % K_2O) for 1 ha area if application rate of N, P_2O_5 and K_2O are 120, 60 and 40 kg/ha, respectively.
5.	A farmer wants to use FYM (0.5 % N, 0.25 % P_2O_5, 0.5 % K_2O), urea (46 % N), SSP (16 % P_2O_5) and MoP (60 % K_2O) @ 100 kg, 60 kg and 30 kg, respectively. Calculate the amount of FYM and fertilizers for 1 ha area, if one-forth of nitrogen is supplied through FYM.
6.	A farmer wants supply whole quantity of nitrogen through FYM in which nutrient content is 0.8 % N, 0.3 % P_2O_5 and 0.6 % K_2O. The application rate is 120:60:40 NPK kg/ha. Calculate the amount of compost, SSP and MoP for 1 ha area.

NOTES

NOTES

कृषिमूला ऋद्धिः

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ICAR

PRACTICAL MANUAL

Agron. 4.5

WEED MANAGEMENT (2+1)

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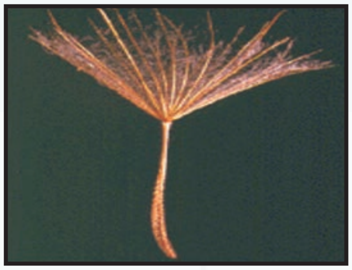


B.Sc. (Hons.) Agriculture

Prepared and Complied by

Dr. R. R. Pisal

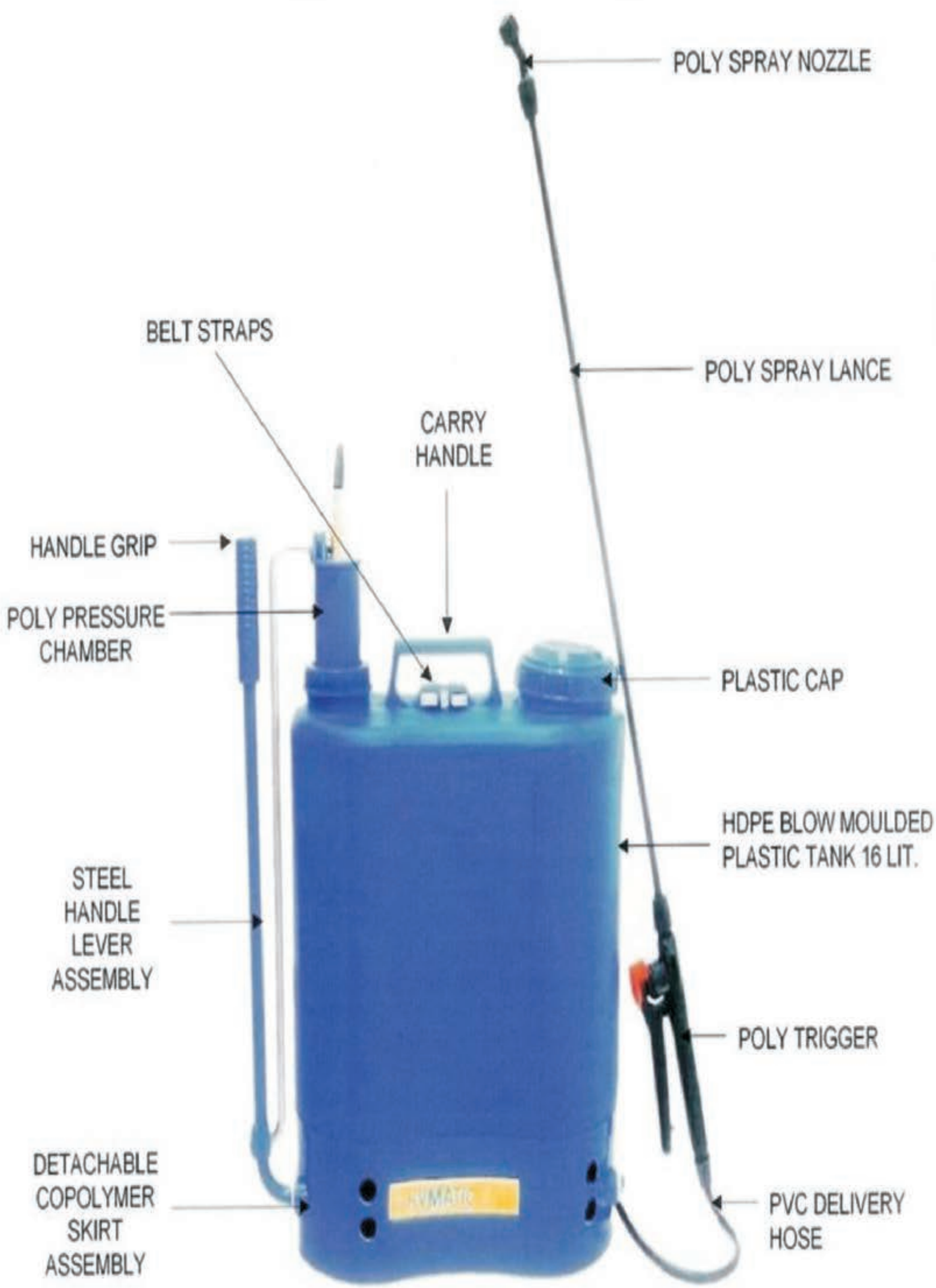
Dr. V. R. Naik

Dr. A. P. Patel

Prof. S. S. Sonawane

College of Agriculture
Navsari Agricultural University
Waghai - 394730

HYMATIC
KNAPSACK ALL-PLASTIC SPRAYER 16 LIT.
ILLUSTRATION OF PARTS



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FOREWORD

A new course on Weed management has been designed in agricultural universities at undergraduate as per syllabus laid out by the 5^{th} Deans Committee recommendations of ICAR. The 36^{th} academic council meeting of NAU, held on 25^{th} April 2017, with item note 36.05. and approved 5^{th} Dean recommendation from the year 2017-18 along with the detail distribution of courses.

The manual contains very basic and practically useful information on identification of weed, weed preservation techniques, herbicides\ compatibility with agrochemicals, herbicides mixture for crops, methods and equipments for herbicide application, shift of weed flora and biology and management of problematic weeds besides this various calculations on herbicide dose, spray volume required and evaluation of herbicide effect by growth indices like weed index and weed control efficiency stepwise. An attempt is being made in this manual to compile the available up-to-date information on the subject in the most easily understandable manner and to make the information user-friendly.

I am sure that this manual will clear the basic concepts of weed management and it will be a useful ready reference material for all the students of first semester B.Sc. (Hons.) Agriculture. I shall feel more than satisfied, if this manual would serve the purpose of students in pursuit of their academic goals. I convey my hearty congratulations to Dr. Dr. R. R. Pisal, Dr. V. R. Naik, Dr. A. P. Patel, Prof. S. S. Sonawane for their commendable efforts in bringing out this practical manual.

Place : Waghai
January, 2019

Dr. Z. P. Patel
Principal & Dean
College of Agriculture, Waghai
Navsari Agricultural University

Reg. No. : ____________ **Batch No.: ____________**

Roll No. : ___________ **Uni Seat No.: ___________**

CERTIFICATE

This is to certify that Mr./Miss. ____

Reg. No. _______________ has completed all the necessary exercises in practical course No. **Agron. 4.5, Weed Management (2+1)** for the requirement of III Semester for the academic year 20 -20 .

Course Teacher	**Professor and Head**	**External Examiner**
Asstt. Prof. of Agronomy	**Dept. of Agronomy**	

Place :

Date :

INDEX

EXERCISE NO. 1

IDENTIFICATION OF DIFFERENT WEED

OBJECTIVES: To know various common farm weeds.

What is a weed?

1. Any plant not sown in the field by farmer is out of place in known as weed.
2. Any plant that is found out of its place where it is not desired is termed as weed.
3. Such plants are undesirable, not only compete with crop plants, but also interfere with agricultural operations, increase, the cost of labour and tillage and ultimately affect yields and quality of farm produce adversely.

About 30,000 species of weeds have been listed in the world, out of which many weed species cause serious damage in different ways resulting in considerable losses to agricultural production.

List of common farm weeds:

Sr. No.	Common name	Scientific Name	Family	Growth Habitat and kind of plant
1.	Amaranthus (Tandalja)	*Amaranthus viridis* L.	Amaranthaceae	K,A
2.	Wild oat	*Avena fatua* L.	Gramineae	R,A,H
3.	White cock's comb (Lampdu)	*Celosia argentea* L.	Amaranthaceae	K,NC
4.	Lamb's quarter (Chill)	*Chenopodium album L.*	Chenopodiaceae	R
5.	Field bind weed (Chandanwel)	*Convolvulus arvensis* L.	Convolvulaceae	P,H,O
6.	Bermuda grass (Dharo)	*Cynodon dactylon* L.	Gramineae	P,H,O
7.	Purple nut sedge (Chidho)	*Cyperus rotundus* L.	Cyperaceae	P,K,H,O
8.	Eclipta (Bhangra)	*Eclipta alba* L.	Compositae	K,O,A
9.	Jungle rice (Samma)	*Echinochloa colonum* L.	Gramineae	A,H
10.	Dudheli	*Euphorbia hirta* L.	Euphorbiaceae	K,L,O
11.	Little seed, Canary grass	*Phalaris minor* L.	Gramineae	R,A,H
12.	Johnson Grass (Baru)	*Sorghum halepense* L.	Gramineae	P,K,NC
13.	Mexican daisy (Ekdandi)	*Tridax procumbens* L.	Compositae	K,A,O,NC
14.	Lantana	*Lantana camera* L.	Verbenaceae	P,W,NC
15.	Kans grass	*Saccharam spontaneum* L.	Gramineae	P
16.	Prickly brinjal (Bhoi ringani)	*Solanum xanthocarpus* L.	Solanaceae	A,Gl,NC,P
17.	Cocklebur (Gadar)	*Xanthium strumarium* L.	Compositae	A,Gl,NC,O

18.	Spiny amaranth	*Amaranthus spinosus* L.	Amaranthaceae	K,A
19.	White sweet clover (Methyu)	*Melilotus alba* L.	Leguminosae	R,A
20.	Mexican Poppy (Satyanashi)	*Argemona Mexicana* L.	Papaveraceae	R,NC,Gl,D
21.	Indian purslane (Luni)	*Portulaca oleracea* L.	Portulaceae	A,R,K
22.	Wetland amaranth (Khakhi weed)	*Alternanthera sessilis* L.	Amaranthaceae	K,A
23.	Jimson weed	*Datura stramonium* L.	Solanaceae	N,C
24.	Carrot grass (carrot grass)	*Parthenium hysteroporus* L.	Compositae	Gl,A
25.	Dodder (Amarwel)	*Cascuta reflexa* L.	Conlovulaceae	P,Parasite
26.	Broom rape (Vakumbha)	*Orobanche cernua* L.	Orobanchaceae	R
27.	Witch weed (Agiya)	*Striga lutea* L.	Scrophulariaceae	K,A, Parasite
28.	Alligator weed	*Alternanthera spp.*		
29.	Bhoi amali	*Phyllanthus niruri* L.	Euphorbiaceae	K,A
30.	*Water hyacinth (Jalkumbi)*	*Eichornia crassipes Solms*	Pontenderiaceae	A
31.	*Wild mustard (Jangali rai)*	*Brassica arvensis Kuntze*	Cruciferae	K,R,H,NC
32.	Common Vernonia	*Vernonia cinera* L.	Compositae	K,A
33.	Wild ber (Bordi)	*Zizyphus rotundifolia* L.	Rhamnaceae	P,NC,DI
34.	Digera	*Digera arvensis* L.	Amaranthaceae	K,H

A= Annual, K= Kharif, H= Herbaceous, R= Rabi, NC= Non crop area,
Dl= Dry land, P= Perennial, G= Grass land, O= Orchard

*** Visit to field**

****

EXERCISE NO. 2

TECHNIQUES OF WEED PRESERVATION

OBJECTIVES:

- How to collect weed specimens
- Steps in preparation of herbarium
- Preservation of weed specimen in chemicals

A) PREPARATION OF HERBARIUM:

Herbarium is a collection of plants that are dried, pressed and preserved on herbarium sheets and arranged in sequence in accordance of specific purpose for future reference, record and study.

Materials required

1) Sharp knife / scalpel – for cutting
2) Vasculum – It is a container made up of wood having a lid to keep the specimen in turgid condition
3) Plant press
4) A weed note book

Herbarium collection

- Collect the plant material at flowering stage
- It is desirable to maintain all the plant parts intact (leaf, stem, flowers and fruits)
- Collect fresh part of the plant but not diseased preferably apical part

Herbarium pressing and drying

- The wooden press board consist of 2 wooden plates of 12”x13” each which are tighten with nuts on bolts for pressing.
- Placing each of the collected specimens in between the folds of the newspaper for blotting.
- Ensure that plant is maintained.
- The specimen in newspaper folds are to be arranged on the lower part of the pressing board.
- Place upper plate on the top and tighten upper and lower parts with nuts and bolts.
- Keep the specimen for 24 hrs for sweating of moisture. This is called as Sweating period.
- Ensure that the specimen is spread in the newspaper folds and if necessary the top portion should be bent during pressing.
- The large specimens are to be cut in 2 to 3 parts according to convenience the cut parts are to be arranged on separate sheets.
- If the specimen can't be directly dried they have to be preserved by preservatories.
- If the foliage is very thick, it has to be pruned assuring that the portion of the cut parts are identified.
- If the leaf is large, cut it vertically into 2 halves use one of the portions as specimen.

- The newspaper/bolting paper changed after 12 hrs in first incidence and these after 24 hrs, 48 hrs and 72 hrs is done till the specimen is dried completely. This is called Natural drying.
- In artificial drying, after sweating period specimens are direct in hot air oven by maintaining 62^0C.

Herbarium mountings

1. Thick herbarium sheets of 11 ½" x 16 ½ "are used for mounting.
2. Keep the specimen in centre and spread properly.
3. Fix the specimen to the mounting sheet with glue / gum / tape.

Herbarium labeling

- Use separate sheet for each weed sample.
- Label the specimen in the space provided 4 ½ x 3 ½ on lower right side of the herbarium sheets.
- Label the weed sample by following order:

  a) Local Name b) English Name c) Botanical Name d) Family c) Economic importance
- Arrange the herbarium by group into terrestrial and aquatic weeds, sub group them into monocots and dicots and further into annuals, biennials and perennials.
- Number the herbarium sheets, serially on the top right corner of the sheet.
- Write the index for it.

Things to do

1) Collect 65 weeds.
2) Collect seed samples in 10 weeds for identification, study and record.
3) Select well spread specimen with natural color and all parts intact.
4) Reject discoloured, folded, wrinkled specimen which are unfit for herbarium.

B) PRESERVATION OF PLANT SPECIMENS IN CHEMICALS:

Plant/weed specimens could be preserved in the following ways:

1. **Formalin solution (5%):** A 5% formaldehyde solution is normally used for preservation of plant specimens. It is prepared by diluting concentrated formaldehyde solution with water and is mainly used for specimens meant for gross anatomical work.

2. **Solution I:** Formalin is not recommended for preservation of the plant specimens meant for finer anatomical work since it hardens the tissues and disfigures considerably the finer interior details of plants. Hence, Santpau (1955) recommended a mixture solution containing ethyl alcohol (95%) 50 ml, glacial acetic acid 5 ml, formaldehyde (40%) 10 ml water and 35 ml per every 100 ml solution for finer anatomical work and even for cytological and embryological work.

3. **Solution II:** To preserve the green colour of plant materials intact for class work, again another mixture solution containing ethyl alcohol (50%) 90 ml, commercial formaldehyde 5 ml, glycerine 2.5 ml, glacial acetic acid 2.5 ml, cupric chloride 20 g and uranium nitrate 2.5 g per every 100 ml of solution is useful. For normally yellow-green colour of foliage, half the quantity of cupric chloride mentioned here is used.

Assignment: Collect various common farm weeds and prepare a "Weed album".

****

EXERCISE NO. 3

STUDY OF LIST OF COMMONLY AVAILABLE HERBICIDES IN THE MARKET AND THEIR NOMENCLATURE

OBJECTIVES: To know the common herbicide available and used for weed control

Herbicides are chemicals capable of killing or inhibiting the growth of unwanted plants. or Chemicals that are used to kill plants or weed are called herbicide e.g. 2,4-D, Pendimethalin, atrazine etc.

The use of herbicide is increasing rapidly since 1944 when 2,4-D was first used as a herbicide. Many new chemicals have become available for weed control. At present, every type of weed control can be solved with herbicide.

List of commonly available herbicides and active ingredient

Common names	Trade name	Percentage
Alachlor	Lasso	50EC
Anilofos	Aniloguard	30EC
Atrazine	Atrataf	50WP
Butachlor	Machete	50 EC
Clomozone	Command	50EC
Ethoxysulfuron	Sunrise	15 WG
Fenoxaprop-p-ethyl	Whipsuper	10EC
Glyphosate	Glycel / Roundup	41SL
Metolachlor	Dual	50EC
Imazethypr	Persuit	10EC
Oxyfluorfen	Goal	25EC
Oxadiargyl	Raft SC, Topstar WG	6EC
Paraquat	Gramoxone	24SL
Pendimethalin	Stomp	30EC
Pretilachalor	Rifit	50EC
Pretilacholar-S	Sofit	30.7% EC
Pyrazosulfuron-ethyl	Saathi	10WP
Quizalofop-ethyl	Turgasuper	EC
2,4-D	Fernoxone	80WP
2,4-DEE	Agrodon	48EC
Isoproturon	arelon	75%WP
Propanil	Stam F 34	34%EC
Thiobencarb	Saturn	50%EC
Trifluralin	Tip top	48%EC
Metaxuron	Dosanex	80%WP
Bis -pyribac sodium	Nomini Gold	10%EC

NOMENCLATURE OF HERBICIDES

There is often more than one formulation of a particular herbicide. This can make selection and application of various products somewhat confusing. Any approved herbicide is known by three names a common name , a chemical name and trade name (sometimes more than one)

Three Names of a Herbicide

Common name of a herbicide is normally one (unless some abbreviated term used Eg. dinoseb/DNBB propham/lPC, chlorpropham/ClPC, chlorthal-dimethyl/DCPA) by which the herbicide is known/pronounced every where in the world,

Chemical name represents the IUPAC (lnternational Union for Pure and Applied Chemistry) name which is based on chemical make-up of the herbicide.

Trade name may vary across companies manufacturing it and, therefore, a herbicide may have many trade names.

EXAMPLE

glyphosate is the common name

N-(phosphonomethyl) glycine is the chemical name

and

Roundup (by Monsanto Enterprises Ltd.),
Glycel (by Excel Crop Care Ltd.) and
Weedoff (by De-Nocil Crop Protection Pvt. Ltd.)
are the trade names.

At present 5l companies of the world manufacture glyphosate and,
therefore, it may likely have 5l or more trade names.

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EXERCISE NO. 4

HERBICIDE LABEL INFORMATION AND PRECAUTIONS IN USE OF HERBICIDES

OBJECTIVES:

- To acquaint with the information on herbicide product labels
- To acquaint with precautionary measures in order to avoid the herbicide injuries

The information on an herbicide label is very important. It helps applicators make sound decisions on herbicide storage, handling, application, and disposal. Every herbicide container carries certain information on its label. This information includes the trade name, technical name, composition, manufacturer's address, registered uses, date of packing, date of expiry, and toxicity label, and is mandatory under the Insecticide Act, 1968.

Material safety data sheets (MSDSs) are developed by product manufacturers. These are a major source of information on herbicides. MSDSs are not legal documents. The information on a MSDS is based on research data. This supports label information. MSDSs also have information to protect human health and the environment. MSDSs help applicators to make informed decisions on handling, applying and storing herbicides.

Components of a Label

A herbicide label has two parts (1) The front or principal display panel and (2) The back or secondary display pan.

Principal Display Panel

The principal display panel is the front of an herbicide product label. This panel contains information to identify an herbicide in a number of ways. There are nine items on the principal display panel

List of items on principal display panel

1. Trade name or product name
2. Class designation
3. Use or purpose
4. Registration number (P.C.P. Act number)
5. Guarantee statement
6. Directions to read the label
7. Precautionary shapes, symbols, and pictograms
8. Net contents
9. Name and address of the registrant

1. Trade name or Product name:

The trade or product name includes

A. The brand name or trade name registered with the Pest Management Regulatory Agency

B. The formulation of the herbicide (this is either printed in full or shown as an abbreviation

C. A description of use. This herbicide is a herbicide used to control weeds.

2. Class designation

There are four classifications (i) Domestic, (ii) Commercial, (iii) Restricted and (iv) Manufacturing

Domestic Class

Domestic class herbicides are registered for home use. They are packaged in small containers for a single application or use season. Domestic class herbicides pose a low risk to users or the environment

Commercial class (Agricultural or Industrial)

Commercial class herbicides are designed for use in farming, forestry, industry or other commercial uses. Commercial class herbicides can pose a greater risk because of the greater concentration of the active ingredient or larger container size.

1. Restricted class

Restricted class herbicides have more limits than Commercial class herbicides.

2. Manufacturing class

Manufacturing class herbicides are used in manufacturing, formulating, or repackaging. They are not designed for general use.

3. Use or Purpose

The use of an herbicide refers to the type of pest it is intended to control. This use (e.g. as an insecticide, a herbicide or a fungicide) will always be clearly stated on the principal display panel of a herbicide label.

4. Registration number (P.C.P. Act Registration number)

It can appear as REG. NO. 12345 P.C.P. ACT or registration number 12345. This number can be used to find an herbicide's Chemical nature, poisoning symptoms, first aid treatment information and environmental toxicity.

5. Guarantee

The guarantee gives the common name of the active ingredients and the concentration of each. The active ingredient is the part of the herbicide that controls the pest.

6. Directions to "Read the Label"

READ THE LABEL BEFORE USING. The label contains key information on proper storage, handling and use.

7. Precautionary Shapes, Symbols and Signal Words

Symbols (shapes and pictograms) and signal words indicate the type of hazard posed by a given herbicide. These are regulated under the Pest Control Products Act and must be included on the label.

A toxicity label on a container conveys the toxicity hazard of the herbicide to mammals, mainly human beings, which is shown in a square or a diamond, divided into two equal inverse triangles. The lower triangle is brightly coloured whereas, the upper contains warning words and signals.

There are four toxicity classes of herbicides, which are represented by bright red, yellow, blue and green colours in the lower triangle—their toxicity decreases in that order. The hazard ratings or the toxicity classes, are based on the acute toxicity represented by LD_{50} (median lethal dose) values. The LD_{50} value is nothing but "the dose of the herbicide (active ingredient) required to kill 50 per cent of the test population, generally rats, when orally treated," and is expressed as mg/kg of the body weight.

Lesser the LD_{50} value more toxic the herbicide is and vice versa; e.g an herbicide with a LD_{50} value of 10 will be more toxic than the herbicide having an LD_{50} value of 100—in other words, for a person weighing 60 kg a dose of 600 mg of active ingredient of the former category of herbicide will prove fatal, whereas, in the latter case a dose of 6000 mg is required for the same. Except for Bt (Dipel, Halt, etc.) and plant-based formulations (Neem formulations) and some new generation herbicides are provided with a green label.

8. Net Contents

The net contents indicate the amount, by weight or volume, of herbicide in a package. This is given in metric units (ml, L, g, kg, etc.).

9. Name and address

The name and address of the company or organization that registered the herbicide (registrant) must appear on the label

Secondary display panel

The back or side of a label is called the secondary display panel. The secondary display panel may be a small booklet attached to the label

List of items on secondary display panel

- Directions for use
- Precaution statements
- Disposal methods
- First aid
- Toxicological information
- Notice to user
- Notice to buyer

Material safety data sheets (MSDSs)

A Material Safety Data Sheet (MSDS) provides information on health hazards, personal safety and environmental protection for hazardous products. They are divided into nine sections.

1. Product information

Product information gives the trade name, chemical name, and primary use of the Product

2. Hazardous ingredients

The active ingredient is listed in this section

3. Physical data

Physical data includes information on a product's appearance, odour, specific gravity, pH, boiling point, etc.

4. **Occupational procedures and prevention measures**

Occupational procedures and prevention measures provide information on safe handling and storage.

5. **First aid and emergency procedures**

First aid and emergency procedures explain what to do if someone is exposed to the product.

6. **Fire and explosion hazard**
7. **Reactivity data**

Special chemical properties of the product are given in this section. Acceptable storage temperatures are listed for the product.

8. **Preparation date and group**

This section tells who prepared the MSDS and when it was done. MSDS s must be updated at least every three years, or within 3 months if a herbicide is changced.

Instruction for Safe Use of Pesticide

Do's	Don'ts
While Purchasing	**While Purcahsing**
o Purchase from Registered dealers	o Do not purchase pesticides from foot path
o Purchase quantity for single operation	o Do not purchase in bulk for whole season.
o See approved labels on containers/packets	o Do not purchase without approved label
o See Batch No., Reg. No., Date of Mfg./Exp.	o Never purchase expired pesticide.
o Purchase pesticides packed in containers.	o Do not purchase leaked containers
During Storage	**During Storage**
o Store away from house premises.	o Never store pesticide in house premises.
o Keep pesticides in original containers.	o Never transfer from original container
o Pesticides must be stored separately.	o Do not store insecticides with weedicides.
o Stored away from the reach of the children	o Do not allow children at storage place.
o Storage place protected by sunlight and rain	o Do no expose to sunlight or rain water.
While Handling	**While Handling**
o Keep separate during transportation.	o Never carry pesticides along with eatables
o Carry herbicide bulk tactfully at site	o Never carry pesticides on head, shoulder etc.
While Preparing spray solution	**While Preparing spray solution**
o Always use clean water.	o Do not allow pesticide to fall on body parts.
o Use protective clothings viz. hand gloves etc.	o Never avoid reading instructions on label
o Protect your nose, eyes, ears, hands, etc.	o Do not smell the spray tank.
o Read instructions on pesticide container	o Do not use overdose which affect plant
o Use recommended dosage of pesticide.	o Do not eat/drink during during operation
Selection of Equipments	**Selection of Equipments**
o Select right sized nozzles.	o Do not use leaky or defective equipments.
o Separate sprayer for insecticides /weedicides.	o Do not use defective/irrelevant nozzles.

While applying spray solutions	While applying spray solutions
o Apply only recommended dose and dilution. o Spray on cool and calm day. o Conduct spraying on sunny day in general. o Spray should be done in wind direction	o Don't spray on hot sunny or windy day o Avoid spray before and after rains o Avoid spray containers for domestic propose o Don't allow animals to enter in sprayed field
After Spray Operation	**After Spray Operation**
o Dispose left over spray solutions o The used/empty containers should be crushed o Wash hands & face with clean water and soap o Give first aid in poisoning symptoms give the first aid and show the patient to doctor	o Don't use containers for storing other articles o Don't eat/smoke before taking bath. o Do not take the risk by not showing the poisoning symptoms to doctor

Exercise:

Q.1 Why spraying should not be carried against the wind direction?

Q. 2 While spraying the herbicide one has to walk back. Why?

Q. 3 Precautionary measure when person taken the herbicide orally?

Q. 4 Precautionary measures while storing the herbicides?

Q. 5 Precautionary measures while preparing the herbicide spray solutions?

Q. 6 Precautionary measures while spraying the herbicide?

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EXERCISE NO. 5

STUDY OF HERBICIDE FORMULATIONS

OBJECTIVES:

- Ease of handling
- High controlled activity on the target plants

Need for preparing herbicide formulation

- To have a product with physical properties suitable for use in a variety of types of application equipment and conditions.
- To prepare a product which is effective and economically feasible to use
- To prepare a product which is suitable for storage under local conditions?

Herbicides in natural state may be solid or liquid, volatile or non-volatile and soluble or insoluble. These cannot be applied in original form; these have to be made in to suitable and safe forms for their field use. Such forms are called herbicide formulations. The herbicide formulations are diluted in water but sometimes in oil also, before their application. Dry granules of herbicide formulations, however, are applied either as such or after their dilution with dry sand, and like material.

An herbicide formulation is prepared by the manufacturer by blending the toxicant (active ingredient) with substances like solvents, invert carriers, surfactants, antifoaming agents, stickers, stabilizers, etc.

The two major objectives of formulating herbicides are to ensure their (a) ease of handling and (b) high controlled activity on the target plants.

A herbicide formulation may be in one of the following forms:

1. Emulsifiable concentrate (EC)
2. Water soluble concentrate (SC)
3. Wettable powders (WP)
4. Dry flowables (DF)
5. Flowable liquid (FL)
6. Granules (G)
7. Others – Capsules, pellets, wax bars, soluble mulches, foam pieces, aerosols etc.

Herbicides are not used in dust forms for fear of their drift hazards, which may be intense.

Sprayable concentrates:

A sprayable concentrate may be in the form of (i) soluble concentrate, (ii) emulsifiable concentrate, (iii) wettable powder or (iv) dry flowable. Water as carrier these herbicide concentrates form solutions, emulsion, or suspensions. They are collectively designated as sprayable concentrates.

1. Emulsifiable concentrate (EC)

An herbicide emulsion is a heterogeneous system. The active ingredient or herbicide concentrate is dissolved in solvent (and vice-versa), where each component maintains its original identity as minute globules. An emulsifying agent must be added to it for uniform distribution of chemical in water. Eg: 2,4-D ester, Alachlor, Diallate

2. Water-soluble concentrate (SC)

A) Soluble liquid (SL): Formulations are in the form of soluble liquids. It is a physically homogenous mixture of herbicide concentrate and the carrier (usually water). Amine salts of 2,4-D, 2,4 5- T, diquat, paraqut and isopropyl amine salt of glyphosate and imazethapyr.

B) Soluble powder (SP): Soluble powder formulations are similar to solutions (S) in that, when mixed with water, these dry formulations dissolve readily and form a true solution. The formulation is dry and consists of the active ingredient and additives.

C) Soluble granules (SG): Soluble granules are dry and larger particle size than soluble powder. They are soluble salts of various compounds. Considerable stirring or agitation may be needed to dissolve these herbicides, but once in solution they remain in that state indefinitely. They form clear solutions in the sprayer tank and require a surfactant for maximum foliar activity. Typical formulation contain 40 to 95 % active ingredient.

3. Wettable powders (WP)

In an herbicide suspension the fine particles of the wet table powder are dispersed in a suitable carrier. To prepare a suspension, first the wettable powder is turned into slurry with limited amount of the carrier and then it I s extended to required volume by adding remainder of the carrier to it. Both suspensions and emulsions of herbicides require mild agitation in the spray tanks. Herbicides sold as wettable powders are atrazine 80%WP, diuron 80%WP, and isoproturon 70% WP and almix20% WP.

4. Dry flowables (DF) or Water dispersible granules (WDG, WG, DG)

Dry flowable and water-dispersible granule formulations are much like wettable powders except that the active ingredient is formulated on a large particle (granule) instead of onto a ground powder. Lexus (50DF) and carfentrazone ethyl (affinity 40DF).

5. Flowable liquids (FL)

Herbicides like acrolein and aromatic solyents are applied in water bodies as flowable liquids, direct from the container under pressure, without any dilution. These are known as flowable liquid formulations. In the water body under treatment, these form either emulsions, solutions, or both (triple phase system), as the case may be.

6. Granules (G)

These are made by loading the toxicant on some dry, inert material, usually attaclay. The herbicide granules vary in size from 0.04 mm to 1.0 mm in diameter. Herbicide granules smaller than 0.04 mm are not used because they drift easily with wind.: Eg: Butachlor, 2,4- DEE.

A) Advantages

- The foremost advantage of granular herbicides is their application convenience for odd situations, like rice paddies, hilly terrain, and water bodies.
- Most herbicide granules neither irritate skin nor corrode or eat through the containers as some liquid herbicides.
- These are easy to transport and possess good storage properties.
- Herbicide granules are safe to the non-target plants because of their freedom from drift hazards.
- The granular herbicides provide better selectivity to the standing crop plants than sprays since the granules bounce-off the crop foliage.

- Granular forms of volatile herbicide molecules like EPTC and trifluralin are saved much longer in soil.
- Herbicide granules are easy to mix with fertilizers, when required.

B) Disadvantages

Despite many advantages, the granular herbicides have not been able to fully replace the herbicide spray systems because of their certain inherent weaknesses, as follows:

- Granular herbicides are low analysis compounds; usually they contain 2 to 10% active ingredient as against 20 to 90% in the Sprayable herbicide concentrates.
- Combinations of two or more herbicides are difficult to make with granular formulations. Granular herbicides require more soil moisture to activate then than the spray liquids.
- Calibration of mechanical granule distributors is much more difficult than the sprayers. The distributors must be recalibrated each time the granules of a different grain size and analysis are used.
- Only soil active herbicides can be used at the present in the granular forms.
- Certain herbicides, such as triazines, persist in soils in granular form much longer than their spray liquids. This increases chances of causing serious injury to the susceptible, rotation corps.

7. Others – Capsules, pellets, wax bars, soluble mulches, foam pieces, aerosols etc.

A) Microencapsulated formulations (ME) or capsule suspension (CS): Microencapsulated formulations are small particles consisting of a herbicide core surrounded by a barrier layer, usually made up of a polymer shell. They also are referred to as capsule suspensions because the capsules are suspended in a liquid medium. Microencapsulation greatly reduces the amount of solvent needed.

B) Pellets (P) or tablets (TB): Pellets are dry formulation of herbicide and other components in discrete particles usually larger than 100 mm^3, tablets are in the form of small flat pellets. Pellets and tablets frequently are used for spot applications. Herbicide concentrations typically are 5 to 20 %.

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EXERCISE NO. 6

STUDY OF HERBICIDE MIXTURES FOR CROPS

OBJECTIVES: To know the different ready mix and tank mix herbicides

To know the herbicide mixture used for different crops

HERBICIDE MIXTURES

"On principle, mechanical or chemical mixing of two or more herbicides having different mode of action and varying level of activity and selectivity, forms "herbicide mixture."

Herbicide combination or mixtures are used for effective and economical weed control. Herbicide combination offer certain advantages like: (i) broad spectrum of herbicidal action, (ii) synergistic or active effects, (iii) prevention of detoxication of one of the herbicide in the mixture, (iv) reduction of the doses of the herbicides etc.

KINDS/TYPES OF MIXTURE

Herbicide mixtures are of two kinds:

1. Factory-mix/pre-mix/ready-mix

It is the mixture of desired herbicides prepared in the factory itself with definite proportions.

Example: isoguard *plus* (isoproturon + 2,4-D), aniloguard *plus* (anilofos +2,4-D), primagram (atrazine 250 g FW + metolachlor 250 g FW), primextra (atrazine200 g FW+ metolachlor 300 g FW), Atlantis [Mesosulfuronmethyl (3%) +iodosulfuron-methyl sodium (0.6%)] etc. One ready-mix Pursuit Plus [pendimethalin (30%) + imazethapyr (2%)] for broad-spectrutn weed control in soybean is also available in India. Almix [metsulfuron-methyl (10%) + chlorimuron-ethyl (10%) + 0.2 surfactant] is another ready-mix recommended for rice.

2. Field-mix/tank-mix

It is a mechanical mixing of two or more herbicides with their required quantities in the spray tank right before applying to the field.

Example: atrazine + alachlor, atrazine + pendimethalin, isoproturon + tralkoxydim, sethoxydim + chlorsulfuron, sethoxydim + thiometuron, fluometuron + chlorsulfirron, are compatible enough to be mixed together for greater efficacy and broad-spectrum weed control in crops in which the respective pair of herbicides is selective.

The number of ready-mix product is less in the market. They are not manufactured as such unless there is sheer urgency towards weed control in certain crop. Ready-mix formulations may fall short towards imparting selectivity to a large number of crops. For example, pendimethalin is a versatile chemical and could be selective to nearly 60 different crops, but its ready-mixes with certain herbicides reduce the mixture's selectivity for use in that many number of crops. Thus herbicide mixture limits the choice of crops and becomes more crop-specific than a single herbicide.

Tank-mix formulation, on the other hand, is mixing of chemicals in the tank before use in the field and, therefore, could be prepared as and when required with exact amount calculated for two or more herbicides. The exact amount calculated based on recommendation is, however, not easy to maintain in ready-mixes.

Ready-mixes are, however, more useful to illiterate farmers than tank-mixes. Once the mixture response is known as synergism or at least additive in certain crop, it would be wiser to resort to tank-mix application.

HERBICIDE MIXTURES FOR CROPS

i) Rice

Several combinations are given below, although, their best use (best recommendation) can be made through further trial and error method. of course, there may not be any objection regarding their compatibility, but interaction has to be modified towards more synergistic response through manipulation of the doses of the component herbicides

- ✓ Anilofos (0.4 kg/ha) + 2,4-DEE (0.50 kglha)
- ✓ Butachlor (1.0 kg/ha)+ propanil (2.0 kg/ha)
- ✓ Butachlor (1.0 kg/ha) + 2,4-DEE (0.5 kg/ha)
- ✓ Benthiocarb (1.0 kg/ha) + 2,4-DEE (0.5 kg/ha)
- ✓ Anilofos (0.3 kg/ha) + chlorimuron (0.004 kg/ha)
- ✓ Anilofos (0.3 kg/ha) + metsulfuron-methyl (0.004 kg/ha)
- ✓ Bentazon + propanil (1604 + 3404 g/litre)
- ✓ Pretilachlor + 2,4-DEE at 4 days after sowing of upland rice

ii) Wheat and Barley

All the following combinations may be used as tank-mix at 28-35 days after sowing of wheat (post-emergence application)

- ✓ Diclofop-methyl (750 g/ha) + fluroxypyr (100 g/ha)
- ✓ Diclofop-methyl (750 glha) + isoproturon (500 g/ha)
- ✓ Isoproturon (750 g/ha) + 2,4-D (250 g/ha)
- ✓ Isoproturon (750 g/ha) + 2,4-D (500 g/ha)
- ✓ Tralkoxydim (350 g/ha) + 2,4-D (500 g/ha)
- ✓ Tralkoxydirn (350 g/ha)+ isoproturon (500 g/ha)
- ✓ Clodinafop (60 g/ha) + 2,4-D (500 g/ha)
- ✓ Clodinafop (60 glha) + isoproturon (500 g/ha)
- ✓ Fenoxaprop-p-ethyl (120 g/ha) + 2,4-D (500 g/ha)
- ✓ Fenoxaprop-p-ethyl (120 g/ha) + isoproturon (500 g/ha)
- ✓ Sulfosulfuron (30 g/ha) + 2,4-D (500 g/ha)
- ✓ Sulfosulfuron (30 g/ha) + isoproturon (500 g/ha)

iv) Soybean

In soybean many herbicides could be used as tank-mixes.

- ✓ Oxadiazon (0.5 kg/ha) + metolachlor (0.5 kg/ha) as pre_emergence
- ✓ Fluazifop-p-butyl (0.75 kg/ha) + fomesafen (0.25 kg/ha) at 20 days after sowing
- ✓ Haloxyfop-methyl (0.20 kg/ha) + fomesafen (0.25 kg/ha) at 20 days after sowing
- ✓ Metribuzin + chlormurom_ethyl as preemergence
- ✓ Pendimethalin (0.5 kg/ha) + fluchloralin (0.625 kg/ha) as pre-emergence (However, this not an ideal mixture)
- ✓ lmazephapyr + pendimethalin - as preemergence.

v) Groundnut

- ✓ Acifluorfen + bentazon + 2,4-DB at 2 weeks (post emergence)

vi) Sunflower

- ✓ Fluchloralin (0.5 kg/ha) + metorachror (0.75 kg/ha) as pre-plant incorporation

vii) Mustard and Rapeseed

- ✓ Pendimethalin (1.0 kg/ha)+ fluchloralin (1.0 kg/ha) as pre-plant

viii) Cotton

- ✓ Pendimethalin (1.5 kg/ha) + diuron (1.0 kg/ha) as pre-emergence
- ✓ Diuron + paraquat as post-emergence directed spray

ix) Sugarcane

- ✓ Diuron + 2,4-D
- ✓ 2,4-D + atrazine/simazine as pre-emergence or post-emergence

x) Potato

- ✓ Atrazine (0.125 kg/ha) + paraquat (0.25 kg/ha) as pre-emergence
- ✓ Atrazine (0.125 kg/ha) + paraquat (0.25 kg/ha) as post-emergence directed spray

xi) Tea and Coffee

- ✓ Paraquat + 2,4-D mixture in tea and coffee usually offers additive response. They are applied as tank-mix and post-emergence to weeds.
- ✓ Paraquat + diurn mixture, although results in in antagonistic effect since paraquat prevents the uptake and translocation of diuron by rapid destruction of foliage and transport system, the residue of diuron in soil remains effective for a considerably long peroid.
- ✓ The mixtures like glyphosate +2,4-D, dalapon +2,4-D and paraquat + oxyfluorfen are also recommended for perennial weed control in these crops. The glyphosate + 2,4-D mixture is synergistic on Cyperus rotundus (Nut sedge), but antagonistic on imperata cylirdrica (Thatch grass) and additive on most other weeds

❑ The success of herbicide mixture, however, depends on

The commercial availability of a large number of herbicides. With only l5-20% herbicides in Indian market, the choice available for weed scientists is too small to select suitable herbicide mixture (Rao, 1993). Many herbicides in mixture show antagonism. Therefore, superior new herbicides with improved synergistic response and eco-friendly nature have to be identified and developed. Expert computer systems need to be developed to find out suitable dose and mixture responses, to recommend control at economic threshold levels and to vary rates according to weed spectrum, density and local environmental conditions.

Herbicide formulations of combination herbicide approved for use in India (till December 28, 2006)

SN.	Combination products	Companies
1.	Anilofos 24% + 2,4-D 32% EC	M/S Aventis Crop Science Ltd., Mumbai
2.	Metfulfuron-methyl 10% + Chlorimuron-ethyl 10% WP	M/S E.J. Dupont India Ltd., Gurgaon
3.	Mesosulfuron-methyl 3% + Iodosulfuron-methyl sodium 0.6% WG	M/S Bayer Crop Science Ltd.
4.	Imazethapyr (2%) + Pendimethalin(30%)	M/S BASF

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EXERCISE NO. 7

DEMONSTRATION OF METHODS OF HERBICIDE APPLICATION

OBJECTIVES:

- To acquaint with different application methods of herbicides

Classification based on methods of application of herbicides:

Methods of application of herbicides are decided largely by their mode of action and selectivity. Important methods of application of herbicides to crop and non-crop lands are given, as follows

Soil-active and Foliage-active Herbicides:

Soil-active herbicide: A soil-active herbicide is one that is applied primarily to the soil rather than to the vegetation. Therefore, in crop fields a soil-active herbicide eliminates early weed-crop competition for the period of 4 to 8 weeks, depending upon the herbicide and its rate used. The soil-active herbicides are applied at the times of planting of crops, and to the weed free inter-rows of established crops to obtain extended period of weed control. E.g. simazine, alachlor, trifluralin, and EPTC. On non-crop lands, the soil-active herbicides used are soil sterilant and fumigants

Different soil application methods:

Surface application: Soil active herbicides are applied uniformly on the surface of the soil either by spraying or by broadcasting. Where they may be either left undisturbed or incorporated into the soil, physically. Eg. Many substituted triazines, urea, and anilide herbicides Eg. EPTC and fluchloralin, trifluralin and nitralin

Sub-surface layering: It is the application of an herbicide in a concentrated band, about 7- 10 cm below the soil surface. The technique has proved effective in controlling perennial weeds like *Cyperus rotundus* and *Convolvulus arvensis*. Eg Carbamate and nitralin herbicides. The useful in orchards and vineyards, besides certain wide-row crops like sugar beet and tobacco.

Band application: The band application of an herbicide constitutes its application to a restricted band along the crop rows, leaving an untreated band in the inter-rows. The band application of herbicides is primarily a cost saving device since it reduces the quantity of herbicide in the ratio of the treated band width to the crop row width.

Soil fumigation: Herbicides used for fumigation are called as fumigants. Depending upon the nature of the soil fumigant, it can be applied either (1) by soil injection (Example, chloropicrin) (2) by releasing it under sealed, plastic covers (Example, methyl bromide) or (3) by direct soil surface application (Eg. Metham).

Herbigation: Application of herbicides with irrigation waters both by surface and sprinkler systems. In India farmers apply fluchloralin for chillies and tomato, while in western countries application of EPTC with sprinkler irrigation water is very common in Lucerne.

Methods of application of foliage-active herbicides:

A foliage-active herbicide is applied to weeds after their emergence from the soil. They are absorbed by the plant foliage and these are translocated to the other plant parts. Eg 2,4,5-T, paraquat, diquat, MCPB, amitrole, and herbicidal oils are common examples of foliage-active herbicides. There may be some herbicides that are both soil-active and foliage-active, for example, 2,4- D, picloram, and atrazine.

Blanket application: Blanket (or over-the-top) it is uniform application of herbicides to standing crops with disregard to the location of the crop plants. Only highly selective herbicides are applied by this method, e.g. 2,4-D in wheat, rice, MCPB in pea, 2,4-DB in Lucerne and picloram in sugarcane

Directed Spraying: It is the application of herbicides to weeds growing in the inter-rows of crops, avoiding the crop foliage as much as possible. Orchards and plantations are good venues of directed herbicide sprays. Usually, the directed spraying is adopted with herbicides that are partially selective to the treated crops.

Protected Spraying: Non-selective herbicides can be employed to obtain selective weed control in distantly planted vegetables and ornamentals by covering the non-target plants before application of the herbicide with plastic or metallic covers. This method is called protected spraying.

Spot treatment: Spot treatment is the application of herbicides to small patches of weeds, leaving the weed-free gaps untreated. This is used for treating patches of noxious, perennial weeds in certain crop fields with potent herbicides. Spot treatment is of value also in the non-crop areas to prevent wastage of herbicide in the weed-free spaces.

Methods of treating brush and trees:

Brush weeds and unwanted trees are treated with herbicides by different methods,. Foliage treatment is the most common method of treating brush.

i) **Foliage treatments**: when the brush leaves are fully expanded, growing actively. Ground sprayers can cover up to 2.5 m high brush

ii) **Basal bark treatment**: A better method of dealing with tall brushes Basal – 30 cm of stem bark. Is peeled off then spraying is done to the point of liberal run-off

iii) **Cut stump treatment**: It comprises sawing of the tree above the ground followed by liberal application of the herbicide on the cut surface.

Other ways by which the concentrated herbicides are applied to unwanted trees are, frill, notch, and injection methods. The frills and notches are made with sharp tools into the sapwood at convenient stem height and filled with herbicides.

The herbicide injections are made into holes made in the tree trunk. Usually, one herbicide injection per 2.5 cm stem thickness is adequate. The frill, notch, and injection methods are adopted on thick stem trees which are 8 cm or more in diameter.

Other methods of herbicide application:

D.C.A. (Direct contact application): D.C.A includes all techniques involving wiping, rubbing, and smearing of herbicide onto the target plant surfaces.

It may be achieved by using herbicide wax bars, herbicide cloth mulch, herbicide rouging gloves, etc. The herbicide laden wax bars are dragged against weeds growing much taller to the crop plants.

Herbicide cloth mulches are spread in the crop inter-rows.

The rouging gloves carry arrangement to smear herbicide on to the weed gripped by the worker. Many other ways of DCA of herbicides can be designed to suit specific situations.

Soil injection: Herbicides like ethylene, carbon bisulphide, and vernolate are applied by soil injections, at prescribed spacings, before planting of the crops.

Exercise:

1. Differentiate band application and directed herbicide application methods

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EXERCISE NO. 8

INTERACTION OF HERBICIDES WITH AGRO-CHEMICALS

OBJECTIVES:

- To know the interactions of herbicide with herbicide, insecticides, fertilizers and fungicide

Under the current agricultural production practices, crops receive, in a single season, multiple seed treatments, preemergence and post emergence herbicides, insecticides, fungicides, nematicides, fertilizers and sometimes plant growth regulators. Most of these chemicals, whether applied as mixtures, simultaneously or sequentially, may undergo a change in physical and chemical characters which could lead to enhancement or reduction in the effect of one or more compounds. A normally safe herbicide may become toxic to a crop or an effective product may show reduced activity on a weed species. These interactions between chemicals are of common occurrence in today's agriculture. Their significance is more evident when the interaction effects are seen much later in the growing season or the following season and year due to build up of persistent chemicals or their residues in the soil. Application of a pre plant insecticide to soil may prove to be toxic when a post emergence herbicide is applied several weeks later. Knowledge of the interaction of herbicides with various chemicals will help in formulating and adopting a sound and effective weed management programme. It can also help to exploit the synergistic and antagonistic interactions between various herbicides to evolve an effective and economical eradication of weeds.

INTERACTION RESPONSES

Interaction is the term used to express the relationship of one agent against the other in a combination. When two or more chemicals accumulate in the plant, they may interact and bring out response different from those obtained when they are used alone. These responses are generally described as additive response, synergistic response (synergism) and antagonistic response (antagonism).

Addition Effect:

The total effect of a combination which is equal to the sum of effects of the components taken independently is called additive effect.

Synergistic Effect:

In this, the effect of combination is greater or more prolonged than the sum of the effects of the two taken independently.

Antagonistic Effect:

The total effect of a combination is smaller than the effect of the most active component applied alone.

Independent Effect:

The total Effect of a combination is equal to the effect of the most active component applied alone.

Enhancement Effect:

The effect of herbicides and non-toxic adjuvants applied in combination is more than that obtained when the herbicides is used at the same rates without adjuvant.

Interaction of Herbicides with Moisture, Fertilizers, Insecticides and Fungicides

1) Herbicide Interactions:

A herbicide may show synergistic response in combination with one herbicide and antagonistic response with another herbicide. The response of one combination may also differ according to the different plant species.

Synergistic Effect:

E .g 2,4-D+ Dicamba.
2,4-D + Atrazine,
Amitrole + Ammonium thiocynate,
Atrazine + Alachlor

Antagonistic Response:

E .g EPTC with 2,4-D or Dicamba in sorghum,
Simazine or Atrazine with glyphosate reduces the activity of glyphosate.

2) Herbicide-Antinode Interactions:

The herbicide antidote interactions are antagonistic in nature. The antidotes like NA, R-25788 and CDAA reduce the toxicity of Herbicdes like alachlor, EPTC and Butylate to certain crops

3) Herbicide- Insecticide Interactions:

Herbicide and Insecticides are often applied simultaneously or serially to crops within a short period. These chemicals are usually not harmful when used as per recommended practices. The tolerance of plants to a herbicide may be altered in the presence of insecticide and vice versa. The Phyto-toxicity of monuron and diuron is increased on cotton when applied with phorate. Similar effects were also observed on oats.

Combination of Organo-phosphate insecticide and Atrazine on phyto-toxicity appeared to involve an effect of the insecticides on herbicides absorption and translocation.

4) Herbicide Interaction with Pathogens and Fungicides:

Herbicides interact with fungicides as the disease causing organisms. Dinoseb was know to reduce the severity of stem rot (White mould) in groundnut.

Diuron and Atrazine which inhibit photosynthesis may make crops susceptible to tobacco mosaic virus. Where as diuron may decrease the incidence of root rot in wheat. Atrazine was found to have antagonistic interaction with the fungicide Dexon on many crops.

5) Herbicide- Fertilizer Interactions:

Application of fertilizer with herbicides is becoming increasingly popular in developed countries. No detrimental properties were observed when herbicide were combined with suspension of fertilizers.

Application of complete fertilizer (Containing N.P and K) reduce the atrazine absorption by plants, thus reducing phytoxicity. Atrazine was more toxic in the presence of PK than in the presence of NP and NK.

Addition of Urea or ammonium sulphate in 2,4-D and glyphosate increased the efficiency of herbicides.

6) Herbicide and Soil Moisture or Irrigation Interaction:

Adequate soil moisture in surface soil is necessary for germination of large population of weeds and their effective killing by herbicides. The adequate soil moisture increase the adsorption and translocation of soil applied as well as foliage applied herbicides which increase efficiency of herbicides in killing weeds. The excess moisture as well as soil moisture stress affect the absorption and efficiency of herbicides and heavy rains after application of herbicides may cause washing away of foliar applied herbicides.

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EXERCISE NO. 9

STUDY OF HERBICIDE APPLICATION EQUIPMENT AND CALIBRATION

OBJECTIVES:

- To study the different Sprayers and functions of different parts of equipment
- To calculate correct amount spray liquid needed per unit area

SPRAYING EQUIPMENTS:

Rocker sprayer

Hand compression sprayer

Foot sprayer

Stirrup pump sprayer

Knapsac sprayer Manual

Knapsac sprayer battery operated

Tractor mounted spray with spray boom

Self propelled light weight boom sprayer

Major components of sprayers:

The important components of sprayers are (i) pump (ii) powers source (iii) tank (v) agitator (vi) distribution system (vi) pressure gauge and (Vii) pressure regulator.

Pump: Any spray liquid must be atomized before it leaves the spray nozzle. A pump provides the necessary pressure for this purpose. Two kinds of pumps are generally used in herbicide sprayers.

Air compression or pneumatic pumps: These pumps force air into an airtight tank containing the spray liquid .The air pressure moves the spray liquid into the nozzle where it gets atomized before leaving the sprayers as fine spray.

Hydraulic or positive Displacement pumps: These pumps take in a definite volume of spray liquid and force it through the delivery system under pressure. The pumps differ in the pressure they produce.

Source of power: A source of power is needed to run the sprayer pumps this source of power may be (a) manual (b) traction (c) motor or (d) tractor and aircraft engines.

Spray tank: A sprayer has either a built in tank or separate tank to carry the spray liquid. The tank should be large enough to avoid frequent refilling. Depending upon the kind of sprayer, the tank size varies from 25 to 2250 liters and sometimes even more. A tank is provided with a large opening, fitted with strainer and a cap to fill the spray liquid. Small tank opening can make filling and cleaning of the tank difficult.

Agitator: Most spray tanks carry an agitator. It may be either a mechanical or hydraulic type. The agitator keeps the spray liquid components in homogenous mixture. The mechanical agitators are usually made in the shape of metal rod with a fan or rings at its distant end.

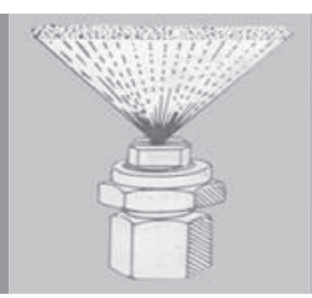
In hydraulic agitation, there is a pipe with several side holes but closed at its free-end. It is placed in the spray tank and is fed under pressure with the spray liquid from the pumps. The jet of liquid thus formed provides the necessary agitation to the spray material. Hydraulic sprayers are provided only in large, tractor-mounted spray tanks. Agitators are most essential for the application of herbicide emulsions and suspensions.

Distribution system: A distribution system of sprayer includes nozzles, spray lance (or spray boom) and hose.

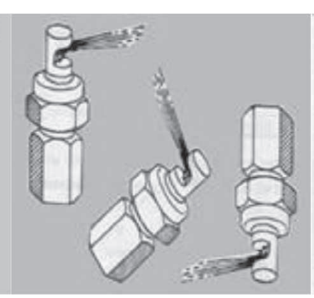
i) Nozzle: The function of spray nozzle is to break the pressurized spray liquid into droplets for application to the target. Nozzles are identified by their (1) droplet size, (2) delivery and (3) spray pattern that they produce. Of the three characteristics, the spray pattern is fixed for a given nozzle (except triple action nozzle).

There are at least six major types of nozzles in use for the application of herbicides. These are (a) flat-fan nozzles, (b) solid cone nozzles, (c) flood-jet nozzles, (d) low volume nozzles, (e) centrifugal nozzles, and (f) blast nozzles.

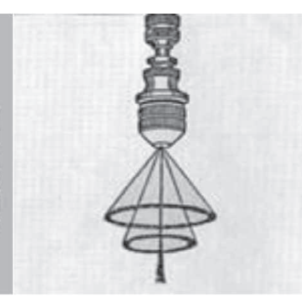
Hollow cone nozzles



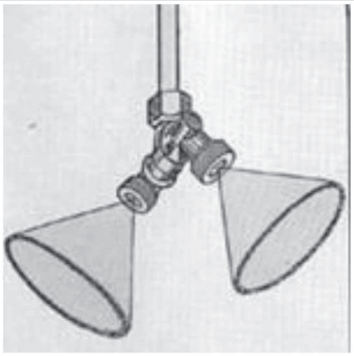
Flat fan nozzles



Floodjet nozzles



Adjustable Single swivel nozzles



Adjustable Double swivel nozzles

The droplet size and delivery of the nozzle will vary with the pump pressure. These droplets are classified according to their Volume Mean Diameter (VMD)* as follows:

Aerosol	: below 50 micron
Mist	: below 100 micron
Fine spray	: 101-200 micron
Medium spray	: 201-400 micron
Coarse spray	: Over 400 micron

***In general, smaller the spray droplet size, more the herbicidal phytotoxicity**.

The **flat-fan nozzles** are again of two types, (a) the 'tapered edge' and the (b) rectangular pattern' nozzles. The tapered edge nozzles provide an even application of herbicides on the soil surface; the rectangular pattern nozzles are good for their band applications. The flat-fan nozzles of both kinds lack the vegetation penetrating capacity. These are, therefore, preferred for the pre-emergence application herbicides. However, these can also be used for post emergence application of the translocated type of herbicides which do not require penetration of the weedy vegetation.

The **solid cone nozzles** provide good vegetation penetrating ability to the sprays, these are useful for application of the contact type of herbicides on dense, weedy patches as spot treatment

The **flood-jet nozzles** produce medium droplet sprays, reducing their drift hazard potentials. These nozzles are commonly used for sub-surface application of herbicides.

The **low volume nozzles** are designed to apply herbicide concentrates without much dilution.

The **centrifugal nozzles** are meant for spraying viscous spray liquids like invert emulsions. Motorized mist blowers employ blast nozzles which feed the spray liquid into the air stream to split it into droplets and carry them as mist, off the delivery pipe.

(ii) Lance: It is a brass rod, about 90 cm long, attached to delivery hose of the sprayer and fitted at its free-end with a replaceable nozzle. In many cases the spray lance is bent at the nozzle end to form a goose neck. At the hose-end it is provided with various types of trigger mechanisms to shut-off the flow of the liquid. For specific purposes, the spray lance may be fitted with plastic shields at its nozzle end to prevent spray drifts.

(iii) Boom (or spray bar): A boom is essentially a horizontal pipe with two to several nozzles on it. Usually, these nozzles are spaced 50 cm apart. The boom length (distance between nozzles at the two ends of the boom) may vary from 1 m to 15 m. Short booms with 2 or 3 nozzles are used with manual sprayers, while the longer ones are attached to the tractor mounted sprayers. A spray boom obviously covers in each trip a wider spray swath than a lance. (Spray swath is the total width of land wetted by a boom. It is slightly more than the boom length). The vertical height of the boom and nozzle spacing on the boom can be adjusted to obtain uniform overall spray, or a directed spray, or a band spray of the herbicide, as per requirement.

(iv) Pressure regulator: Power-driven sprayers are usually fitted with a pressure regulator so as to push the liquid at a constant, desired pressure. Without a pressure regulator, a nozzle will deliver more liquid at one time and less at the other, in the same trip. Moreover, some herbicides are prescribed to be applied at specific pressures to obtain best results.

Kinds of sprayer:

A. Knapsack sprayers:

Knapsack sprayers are loaded on the back of the worker during the operation. Usually they carry metallic tanks, but these are also available with plastic tanks to reduce weight. The plastic tanks are prone at damage by rats though. Three types of knapsack sprayers in vogue today are: (i) hydraulic sprayers, (ii) manual pneumatic sprayers, and (iii) motorized pneumatic sprayers.

i) Hydraulic knapsack sprayers:

A hydraulic knapsack sprayers is a manually operated sprayer which works under hydraulic pressure. Its tank capacity is up to 15 litres, with provision for mechanical agitation of the spray liquid. One tank full of spray liquid can cover an area of about 600 sq m. The worker uses his left hand to operate the lever handle of the sprayer as the lever maintains constant pressure. The output is usually 0.4 ha per man day But it is possible to obtain higher output by replacing the lance with a 2-3 nozzle boom. The hydraulic knapsack sprayer is primarily a high volume sprayer, unless special low volume nozzles are fitted to it. It can develop a pressure of up to 12 kg cm^{-2}, but with practice one could spray at 3 to 4 kg cm^{-2} pressure to prevent a possible spray drift. Hydraulic knapsack sprayer is a low cost, easy to maintain, and a small holding farmer sprayer. It is particularly satisfactory for spot treatment, band application of herbicides and blanket application if it is provided with boom.

The main drawback of a hydraulic knapsack sprayer is its three way tiring action on man, viz, a load on the back, one hand engaged in operating the pump, and the other one in directing the lance.

ii) Pneumatic or compressed system knapsack sprayers:

Pneumatic knapsack sprayers are comparatively easy to work with since they are pressurized before loading on the back of the worker. This allows a free hand to the operator. The tank is first filled to about 2/3 capacity with the spray liquid with a built in pump, separate charge pump or CO2 cylinders. A big drawback of pneumatic sprayers is the decreasing spray work is advanced. This may cause uneven spray. Also, the mouth of these sprayers is small which makes cleaning of the tank cumbersome

The pneumatic knapsack sprayers are useful tools to spray herbicides in odd situations like paddy fields, jute fields, hilly terrain, and water banks.

iii) Motorized pneumatic sprayers (Blowers):

A motorized pneumatic sprayer is a low volume sprayer suitable for spraying concentrated spray liquids. The blast of air acts as carrier of the herbicide concentrates in these sprayers, which are, therefore, also called blowers. The air is forced-through the spraying jet of the delivery hose of the blower and a nozzle tube ejects the spray liquid in this blast. The air blast atomizes the spray liquid into fine droplets. Thus, in these sprayers air acts as the carrier. Faster the air is pumped into the spraying jet, more vigorous is the atomization. The equipment is fitted with petrol engine of about 1.2 H.P.

B. Foot operated sprayers

The pump in the foot sprayer consists of a pump barrel and a pressure chamber. The plunger with a suction cup or piston drives into the pump barrel, thus sucking the liquid into the pressure chamber and expelling it through the discharge line.

Steps in the calibration of sprayers

To determine the exact quantity of water required for an area, adopt the following steps in sprayer calibration.

Step.1. Prepare the sprayer

Check the sprayer and its parts and ensure that it is in good working condition. Fill the sprayer tank with a known quantity of water (say 3 litres.).

Step.2. Mark a test area

Mark out a test area in the field. The land surface used for calibration of sprayer must be similar to the field to be sprayed. Mark the starting point with a stake.

Step.3. Conduct the test run

Work the lever of the hydraulic sprayer a few times and develop enough pressure. Establish on optimum spray swath by adjusting the height of the nozzle. Always maintain constant nozzle height while spraying. After observing these preliminaries, position the nozzle at the starting point and make the test run. Walking must be at a comfortable pace while spraying, and this speed must be maintained throughout calibration, and later in actual spraying. When the water in the sprayer is completely sprayed, measure the length and breadth of the test area sprayed. Check whether and quantity of water is left in the tank. If so, measure it, subtract it from the original quantity taken, and arrive at the correct amount of water consumed.

Step.4. Calculate the application rate

Calculate the amount of water required for 1 ha from the following relationship.

$$\textbf{Volume of water required (L/ha)} = \frac{\text{Volume sprayed (l)}}{\text{Area sprayed (ha)}}$$

$$\textbf{Area sprayed (ha)} = \frac{\text{spray swath (m) x distance travelled (m)}}{10{,}000}$$

Example:

The following details have been generated from a sprayer calibration attempt. Spray swath 1.2 m; distance travelled 60 and volume sprayed 3L. Calculate the volume of water required for spraying 1 ha.

$$\text{Amount of water required for 1 ha} = \frac{3 \times 10{,}000}{1.2 \times 60} = 417 \text{ litres.}$$

As a next step calculate the number of sprayer loads required for 1 ha.

$$\text{Number of sprayer loads/ha} = \frac{\text{Volume of spray solution required (l)}}{\text{Sprayer capacity (l)}}$$

In the above example, if the sprayer capacity is 13 litres, then

$$\text{Number of spray loads/ha} = \frac{417}{13} = 32$$

The spray man should adjust his walking speed and discharge rate of sprayer so as to complete the spraying with the spray loads computed, based on the total volume of water fixed.

Boom sprayer calibration

$$\textbf{R (1/ha)} = \frac{600 \text{ x NDR (1/min per nozzle) x N (No. of nozzles)}}{\text{W (m) x S (Km/hr)}}$$

$$\textbf{Band application rate (1/ha)} = \frac{\text{Band width (cm) X Broadcast rate (l/ha)}}{\text{Row spacing (cm)}}$$

$$\textbf{A (ha)} = \text{W (m) x T (hr) x S (km/hr) x 0.1}$$

$$\textbf{Area (ha) hr}^{-1} = \frac{\text{Walking speed (km hr}^{-1}\text{) x m km}^{-1}\text{ x Spray width (m)}}{\text{m}^2\text{ ha}^{-1}}$$

$$\textbf{T (hr)} = \frac{\text{A (ha) x 10}}{\text{W (m) x S (km hr}^{-1}\text{)}}$$

$$\textbf{The area sprayed (sq. m)} = \text{Distance travelled (m) x swath width (m)}$$

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EXERCISE NO. 10

COMPUTATION OF HERBICIDE DOSE FOR DIFFERENT FIELD CROPS

OBJECTIVES:

1. To calculate correct dose of herbicide
2. To study the different aspects (carrier, spray volume) related to herbicide dosage calculations
3. To calculate correct amount spray liquid needed per unit area

Spraying is the most common method of application of herbicides. Calibration of a sprayer is pre-requisite for safe and effective control of weeds. A sub lethal dose fails to give satisfactory weed control, where poor or no weed control is obtained. On the other hand, overuse may injure the crop in crop land situation and will increase the cost in non crop situation and will accumulate toxic residues in soil. Thus, calibration of sprayer and calculation of accurate amount of commercial product from the recommended dose is essential for effective control of weeds.

Calculations of herbicide dose, volume of water required and area sprayed

Rate of application: It is the amount of active ingredient or acid equivalent of herbicide applied to a unit area of land or water body. It is usually given in terms of kg ai/a.e/ha.

Active ingredient (ai): A chemical in commercial product that is directly responsible for its herbicidal effect is called *active ingredient*.

Active ingredient of each herbicide concentrate or formulation is displayed by the manufacturers on the containers. The above ingredient may also give as percent by weight or volume. Eg. Stomp 30 EC contains 30% pendimethalin as emulsifying concentrate. Herbicide concentrate 30% w/v contains 300g of active ingredient per litre of the liquid product

$$\textbf{The amount of commercial product to be used} = \frac{\text{Recommended dose x 100}}{\text{Active ingradient in product (a.i/a.e)}}$$

Volume: Volume It refers to total quantity of liquid applied per unit area. The quantity of toxicant reaching the target weed or soil is more important than spray volume as much as.The toxicant is uniformly distributed over the target area. The spray volumes for herbicides have been classified into 5 classes from high volume to ultra low volume sprays.

The high volume spray provides thorough coverage of target plants to the point of runoffor drip. Eg: contact herbicides.

But translocated herbicides should be applied in low or medium volume sprays, because it is not necessary to wet the foliage completely. In dry weather, high spray volumes may prove superior to low volume sprays. High volume sprays are necessary to improve the solubility or

suspend ability of a herbicides.

Different classes of spray

Sprays	Spray volume (l/ha)
High volume	more than 600
Medium volume	200-600
Low volume	50-200
Very low volume	5-50
Ultra low volume	less than 5

$$\textbf{Volume of water required (L/ha)} = \frac{\text{Volume sprayed (l)}}{\text{Area sprayed (ha)}}$$

$$\textbf{Area sprayed (ha)} = \frac{\text{spray swath (m) x distance travelled (m)}}{10{,}000}$$

The area sprayed (sq. m) = Distance travelled (m) x swath width (m)

HERBICIDE DOSES :

Exmple 1 :
Calculate the amount of atrazine (50 WP) in kg/ha, if rate of application is 1.0 kg ai/ha.
Solution:
Active ingredient (a.i.) in atrazine = 50%
Recommended dose = 1.0 kg ai/ha

$$\text{So, amount of atrazine (kg/ha)} = \frac{\text{Recommended dose (kg ai/ha)}}{\text{a.i. in herbicide (\%)}} \text{ X } 100$$

$$= \frac{1.0}{50} \text{ X } 100 = 2.0 \text{ kg/ha}$$

Example: 2
Calculate the volume of pendimethalin (30% EC) for 6000 m2 wheat field, if rate of application rate is 1.0 kg ai/ha.
Solution:
Active ingredient (a.i.) in pendimethalin = 30%
Recommended dose = 1.0 kg ai/ha

$$\text{So, volume of pendimethalin (l/ha)} = \frac{\text{Recommended dose (kg ai/ha)}}{\text{a.i. in herbicide (\%)}} \text{ X } 100$$

$$= \frac{1.0}{30} \text{ X } 100 = 3.33 \text{ l/ha}$$

SPRAY VOLUME :

Example: 1
The following details have been generated from a sprayer calibration attempt. Spray swath 1.2 m; distance travelled 60 and volume sprayed 3L. Calculate the volume of water required for spraying 1 ha.

$$\text{Amount of water required for 1 ha} = \frac{3 \text{ x } 10{,}000}{1.2 \text{ x } 60} = 417 \text{ litres.}$$

As a next step calculate the number of sprayer loads required for 1 ha.

$$\text{Number of sprayer loads/ha} = \frac{\text{Volume of spray solution required (l)}}{\text{Sprayer capacity (l)}}$$

In the above example, if the sprayer capacity is 13 litres, then

$$\text{Number of sprayer loads/ha} = \frac{417}{13} = 32$$

The spray man should adjust his walking speed and discharge rate of sprayer so as to complete the spraying with the spray loads computed, based on the total volume of water fixed.

Example: 2

Find out the volume of water required to spray herbicide in 1 ha land from the following details

a) **Distance sprayd (length): : 50 m**
b) **Width of spray swath: : 1.4 m**
c) **Water required: : 2 lit.**

Solution:

Area sprayed (m2) = Distance travelled (m) x swath width (m)

= 50 m X 1.4 m

= 70 m2

70 m2 area requires = 2 lit

10,000 m2 requires = $2 \text{ X } \frac{10,000}{70}$ lit

= 285.7 lit

AREA SPRAYED :

Example: 1

Find out the area sprayed by a full tank of knapsack sprayer from the following details:

a) **Recommended spray volume : 400 lit/ha**
b) **Volume of sprayer : 12 lit**

Solution:

400 lit required = 10,000 m^2

Therefore 12 lit required = $12 \text{ X } \frac{10,000}{400}$ m^2

= 300 m^2

Area sprayed (m^2) = $\frac{\text{Volume of spray (lit) X 10,000}}{\text{Recommended spray volume (lit/ha)}}$

Exercise: Herbicide dose, Volume of water required and area sprayed

1) A farmer wants to apply atrazine to maize @ 0.5 kg/ha in the form of atrataf 50% WP. Calculate the quantity of the herbicide required for one hectare

2) Find out the volume of water required to spray herbicide in 2.5 ha land from the following details:
   a) Distance sprayed (length) : 50 m
   b) Width of spray swath : 1.4 m
   c) Water required : 2 lit.

3) A farmer wants to spray 2, 4-D in 7000 m^2 wheat field. What would be the amount of 2, 4-D and volume of water for spray, if rate of 2,4-D application is 0.5 kg ai/ha, active ingredient is 80% and spray volume of water is 800l/ha

4) A farmer uses knapsack sprayer for application of isoproturon (80%) @ 0.75 kg ai/ha in 8000 m2 area of wheat crop. The capacity of knapsack for spray is 15 litre. The spray volume of water is 450 litre/ha. Calculate the followings:
i) Amount of isoproturon (gram)
ii) Number of knap-sac spray
iii) Amount of isoproturon (gram) in each knap-sac spray

5) A farmer has 5 ha area of maize crop. He has choice to apply pendimethalin (30 EC) or atrazine (50 WP). Which will be economical if, recommended rate of application of pendimethalin is 1.0 kg ai/ha and of atrazine is 1.5 kg ai/ha. The price of pendimethalin is Rs. 400 /lit and of atrazine is Rs. 350/kg

6) Find out the most economic herbicide from their cost point of view from the following information

Symbol	Price (Rs / kg)	a.i. (%)	Recommended Rate
A	360	50	1.1 kg ai/ha
B	450	60	0.70 kg ai/ha
C	320	40	1.70 kg ai/ha
D	1570	12.5	0.05 kg ai/ha

7) Glyphosate has to be applied in 30 cm band in sugarcane with 90 cm row spacing. The recommended rate is 1.6 kg/Ha. How much Glycel 41 SL is needed to cover 5000 m^2

8) The speed of tractor mounted sprayer is 4 km/hr and the width of spray band is 5 m. In how many minutes, the sprayer will cover 1 ha area

9) A tractor mounted sprayer runs in the field for 2 hours at the speed of 5 km/hour and sprays @ 400 litre/ha. Calculate the area covered by sprayer and volume of water sprayed, if width of spray is 6 m.

10) A farmer uses tractor mounted sprayer for spray of pendimethalin (30 EC) @ 1.0 kg ai/ha area. The width of spray is 5 m. The tractor mounted sprayer deliver spray @ 400 l/ha and takes 2 hours for spray in the whole field. Calculate volume of pendimethalin and water for spray and speed of tractor

EXERCISE NO. 11

ESTIMATION OF WEED FLORA AND CALCULATION OF WI AND WCE

OBJECTIVES:

- To find out the number of monocot and dicot weeds associated with the crop
- To compute the weed indices

WEED DENSITY:

Need to measure weed density

- ✓ It is necessary to know the number and nature of weeds competing with the crops. The weed density gives the biological stress that the crops are subjected to.
- ✓ It is easy to measure weed density during early stages (or) critical period of crop- weed competition.

Measurement of weed density:

There are two methods normally adopted for the measurement of weed density.

1. **Counting method**: Here different species of weeds are counted by using the quadrat in a crop field.
2. **Dry matter weight**: By this method, the weeds are cut at the base and record the fresh weight immediately and the dry weight, after drying in an oven are taken to compute the weed density.

Precautions:

- The weed count should be taken after the emergence of weeds but at the initial stage of crop growth itself to facilitate the placement of quadrate.
- Take care to note the name and number of weeds immediately.
- Select at random, the location for placing quadrate in different places of the crop field.

Materials required

- Quadrate of 0.5 m x 0.5m size
- Observation note book
- Pencil

Procedure

- Select a field with young crop plants and weeds for taking weed count. Place the quadrate at randomly selected place in the field
- First pull out all the dicotyledonous weeds inside the quadrate taking simultaneous counting
- Record the number of dicot weeds the observation note book . Then pull out and count all the monocotyledons and record it.
- Multiply the number of monocot weeds by 4 to find out the number of weeds m^{-2}

- In the same way, calculate the number of dicotyledonous weeds/ha

Calculations:

On the basis of above observations, calculate the following:

Area of the quadrate	: 0.5 x 0.5 = 0.25 m^2
No.of monocot weeds/sq.m	:
No.of dicot weeds/sq.m	:
The percentage of monocot. weeds	:
The percentage of dicot weeds	:
No.of monocot weeds/ha	:
No.of dicot weeds/ha	:

EVALUVATION OF HERBICIDE EFFECTS:

The use of herbicides in crop and non crop sitution is increasing day by day. Besides, to judge the efficiency of weedicides as well as weed controls methods, many indices are developed. In this practical, an attempt has been made to discuss the numericals related to indices involved in the control of weeds.

The efficacy of herbicide can be assessed the following methods

Weed index (W I):

$$\mathbf{WI} = \frac{X - Y}{X} \times 100$$

Where,
X = Yield from weed free (hand weeded plots) kg ha-1
Y = Yield from treatment plots kg ha-1

- ✓ **Lesser the WI better the efficiency of that herbicide.**
  We can also compare the efficacy of 2 herbicides with the help of weed index.

Weed control efficiency (WCE) :

$$\mathbf{WCE} = \frac{X - Y}{X} \times 100$$

Where,
Where,
X = Dry matter production of weeds in un weeded plot.
Y = Dry matter production of weeds in treatment plot.

- ✓ **Higher the weed control efficiency better is the herbicide**.

Example: 1. A weed free plot of Sorghum has given yields of 1500 kg ha-1 where as atrazine and simazine treated plots have given yields of 1400 kg and 1450 kg ha-1 respectively, calculate the weed index and give which herbicide as better in the two?

$$\text{Weed index (W.I) of Atrazine} = \frac{1500 - 1400}{1500} \times 100 = 6.66$$

$$\text{Weed index (W.I) of Simazine} = \frac{1500 - 1450}{1500} \times 100 = 3.33$$

Weed index of simazine is less than atrazine, hence atrazine is better herbicide

Example: 2. In a weed control experiment in Groundnut, dry weight of weeds in control plot was 620 kg / ha where as x and herbicide treated plots y, the dry weight was 230 and 360 kg/ha respectively. Find out which herbicide is better amongst two?

$$\text{W. C. E of X} = \frac{620 - 230}{620} \times 100 = 62.9$$

$$\text{W. C. E of Y} = \frac{620 - 360}{620} \times 100 = 41.9$$

Since the weed control efficiency is higher with X, hence it is better than Y.

Exercise:

1. Calculate weed control efficiency and weed competition index of following herbicides applied to groundnut crop. Base on this which herbicide is better among them?

Sr. No.	Treatment	Rate (kg ai/ha)	Dry wt. of weeds (kg/ha)	Yield (kg/ha)
1	Alachlor	1.5	800	1200
2	Nitrofen	2.0	1200	800
3	Pendimethalin	1.0	900	1000
4	Unweeded control	---	3000	500
5	Weed free	---	---	1500

2. Calculate weed control efficiency and weed competition index of following herbicides applied to sugarcane crop. Base on this which herbicide is better among them?

Sr. No.	Treatment	Rate (kg ai/ha)	Dry wt. of weeds (kg/ha)	Yield (t/ha)
1	Metribuzine	1.0	500	90
2	2, 4-D	1.5	700	95
3	Atrazine	2.0	400	100
4	Unweeded control	---	1000	50
5	Weed free	---	---	110

3. **Calculate weed control efficiency and weed competition index of following herbicides applied to sorghum crop. Base on this which herbicide is better among them?**

Sr. No	Treatment	Dry wt. of weeds (kg/ha)	Yield (kg/ha)
1	Unweeded control	1800	500
2	Weed free	--	2500
3	Atrazine	500	2200
4	Pendimethalin	900	2000
5	2, 4-D	1000	2150

4. **Calculate weed control efficiency and weed competition index from the following information.**

Sr. No.	Treatment	Rate (kg a.i.ha^{-1})	Dry weight of weeds (g m^{2})	Yield (kg ha^{-1})
1	Pendimethalin	1.0	50	2000
2	Alachlor	1.0	60	1800
3	Oxyfluorfen	0.2	70	1700
4	Control	-	250	1400
5	Weed free	-	-	2500

5. **Calculate weed control efficiency and weed competition index of following herbicides applied to sorghum crop. Base on this which herbicide is better among them?**

Sr. No.	Treatment	Rate (kg ai/ha)	Dry wt. of weeds (kg/ha)	Yield (kg/ha)
1	Unweeded control	--	1800	500
2	Weed free	--	--	2500
3	Atrazine	1.0	500	2200
4	Simazine	1.5	900	2000
5	2, 4-D	1.25	1000	2150

6. **Calculate weed control efficiency and weed competition index of following herbicides applied to cotton crop. Base on this which herbicide is better among them?**

Sr. No.	Treatment	Rate (kg ai/ha)	Dry wt. of weeds (kg/ha)	Yield (kg/ha)
1	Pendimethalin	1.0	800	2700
2	Diuron	0.75	1200	2000
3	Alachlor	1.0	1000	2100
4	Unweeded control	---	3000	800
5	Weed free	---	---	3100

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EXERCISE NO. 12

FIELD STUDY AND CONTROL OF PROBLEMATIC WEEDS - NUT SEDGE, BERMUDA GRASS, AND PARTHENIUM

OBJECTIVES: To know the biology of different weeds and its management

Common name: **PURPLE NUT SEDGE**

Scientific name: (i) *Cyperus rotundus* L. (Purple nut sedge);
(ii)*Cyperus esculentus* L. (Yellow nut sedge)

Family: Cyperaceae

Biology and habitat

It is very persistent perennial sedge. It is considered as world's worst weed as it occurs in 52 crops in 92 countries. It is native of India and widely distributed throughout tropics and subtropics. The slender underground runners grow out from the base of stem and form series of black irregular shaped or nearly round tubers which may growth up to 2 cm length. The tubers often sprout to produce new plants while still attached to the parent plant. Yellow nut sedge propagate through seeds whereas purple nut sedge propagates through tubers. In mixed stands, purple nut sedge is distinguished by its red, reddish-brown, or purplish-brown loosely arranged inflorescence, dark green leaves which grow low to the ground with boat-shaped leaf tips. Yellow nut sedge has a yellowish-brown or straw-coloured inflorescence which is arranged along an elongated axis in the shape of a bottle brush. It has pale green leaves which grow upright with long needle-shaped leaf tips.

Each spike let is made up of 10-30 small closely crowded florets which ripen to form black triangular nuts, roots are fibrous and extensively branched. The rhizomes give rise to under ground tubers which proliferate intensively. Rhizomes do not give rise to new growth except through tubers. Most of the tubers grow in top 10 cm to 30 cm of soil Tubers store food for other parts of plants and they are effective means of propagation. New tubers are produced within 3 weeks after spouting of an individual tuber. It also propagates through seed. It is sensitive to shade and grows well in wet and dry soil and warm climates. It is a serious weed in many dry land irrigated crops.

Management

- Mechanical methods kill only top growth with little effect on tubers. Herbicides which translocates rapidly into tubers to prevent regeneration are most effective in controlling this
- Summer deep tillage
- Solarization with 1000 guage black film
- 2,4 –D & MCPA at 2-5 kg/ha could control this grass.
- Application of these in addition to trifluralin and exposing tubers or desiccation was more effective than herbicide alone.
- In arid areas it was found that deep cultivation in summer supplemented by 2,4-D Sodium salt at 2-4 kg/ha before onset of monsoon completely controls this grass as it checks the regeneration.
- In humid areas fallow tillage should be shallow and it should be repeated at 18-20 days interval as it is at pre-flowering stage when the food reserve are at low
- Glyphosphate 1 kg/ha is more effective than many foliage applied herbicides.
- Paraquat kills the top but repeated application would deplete the tubers of food reserves and gives better control.
- Atrazine is particularly good for the control of seedling nutsedge.
- Soil fumigation with metham or MB for treating nurseries and pot weeds

Common name: **DOOB GRASS, BERMUDA GRASS, STAR GRASS**

Scientific name: *Cynodon dactylon* L.

Family : Poaceae

Biology and habitat

It is one of the world worst weed. It occurs throughout tropics and subtropics and semiarid regions of world. A fine to robust stoloniferous perennial, mostly with rhizomes. Rhizomes can penetrate 40-50 cm in clay soil and 70-80 cm in sand. Foliage dense, 10-40 cm tall (rarely to 90

cm). Leaves vary greatly in length from 3-20 cm. smooth or hairy on upper surface Inflorescence consist of 4-5 slender purple spikes of 10 cm long. Some varieties used as lawn grass/ it propagate vegetative more than by seeds. It is susceptible to competition and shading. Bermuda grass reproduces by seed production and through runners and rhizomes. A single shoot from a

rhizome may cover 2.5 square m of soil surface in 150 days after its emergence

Management:

- Deep tillage during summer (desiccates by 7-14 days).
- Bermuda grass growth can be reduced by increasing shade from trees and tall shrubs
- Small patches can be dug out but all rhizomes and stolons must be removed. Solarization by plastic sheet is used in sunny locations
- Bermuda grass can be controlled by grass-selective herbicides like sethoxydim (Grass Getter), fluazifop (Fusilade, Ornamec, and Grass-B-Gon), or clethodim (Envoy).
- Deep tillage can be improved by application of dalapon, glyphosate (1.0 - 2.0 kg / ha) and amitrole T.
- Glyphosate and amitrole T are having less residual effect
- Paraquat and diquat are more suitable under more intensive cropping as they are non residual type.
- These chemicals could be applied one week before deep tillage.

Common name: **CARROT GRASS, CONGRESS GRASS**

Scientific name: *Parthernium hysterophorus* L.

Family: Asteraceae

Biology and habitat:

It is a noxious exotic weed which has spread to many parts for country covering 5 million ha. It is annual plant (thermo and photo insensitive). Reaching 2m tall in good soils, usually 50 to 150cm, germinating after rain at any season, flowering in 6 to 8 weeks, and senescing with drought or frost. the stem is branched and covered with trichomes.

Leaves are pale green, lobed, hairy, initially forming a basal rosette of strongly dissected leave that are up to 30 cm in length. Young roselles with their radial leaves closely press to the ground, allow no other species to come up in their vicinity. The number of leaves per plant ranges from 6 to 55. Flower heads are creamy white, about 4 mm across, arising from the leaf forks.

Reproduces by small seeds lasting up to 20 years in soil, induced dormancy on burial the plant is capable of flowering when one month old and remains in flower for 6 to 8 months It produces 5000-10000 seeds/plant. The toxin parthenin is responsible for allergic dermatitis and mental depressions in human being. Plant prefer moist shady and organic rich habitat they have remarkable adaptation to environment extremes which exerts allelopathic influence on the neighboring plant species, the seed leachates inhibit germination of other weed seeds cause allergies and skin diseases. Seeds are light in weight and armed with pappus and disseminated by wind, water, birds and animals. It is not only an agricultural weed but also a municipal weed.

Management

- Mechanical and cultural: Manual uprooting of *Parthenium* before flowering and seed setting is the most effective method. A plant in flower will aid in the dispersal of pollen grains, resulting in allergic reactions.
- Ploughing the weed in before the plants reach the flowering stage and establishing pastures or other plants may be effective
- Competitive replacement of *Parthenium* can be achieved by planting species like *Cassia sericea, C. sparsiflorus, Amaranthus spinosus, Sida acuta, Tephrosia purpurea, Stylosanthes scabra* and *Cassia auriculata*, which will compete with the weed and reduce its population.
- Similarly, planting *Cassia tora* will help to cover and suppress the growth of *Parthenium*. In certain parts of India, crop rotation using marigold (*Tagetes* spp.) during rainy season, instead of the usual crop, is found effective in reducing *parthenium* infestation in cultivated areas.
- 2,4-D, paraquat provide effective control of weed.
- Pre-emergence application of atrazine, alachlor, butachlor prevent seedling emergence up to 2-5 months.
- Chlorimuron @0.2-0.4kg/ha and metasulfuron @0.003-0.0045 kg/ha as pre-emergence.
- Already established vegetation: in non cropped areas 2,4-D esters @2-5kg/ha or common salt @ 15-20% at actively growing stage.
- Biological: The leaf-feeding beetle *Zygogramma bicolorata* and the stem-galling moth. *Epiblema strenuana* are widely used in several countries to manage Parthenium. *Z. bicolorata* is now widely used in India to control Parthenium. The moth significantly reduces flower and seed production of the weed, especially at a young age.

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EXERCISE NO. 13

SHIFT OF WEED FLORA STUDY IN CROPS AND CROPPING SYSTEMS

OBJECTIVES: To know the changes in weed flora in crops and cropping system

WEED SHIFT : It is the change in the composition or relative frequencies of weeds in weed population or community in response to natural or man made environment.

REASONS

Weed flora shifts as a result of plant introduction:

Exotic weeds can become very aggressive in new habit if the ecological conditions are favorable. Problematic weeds introduced are:

- *Eichhornia crassipe* (Water hyacinth) from South America in 1980,
- *Salvinia moilesta* (Water fern) from Brazil,
- Parthenium *hysterophorus* (Congress weed) from Central and North America in 1956
- *Phalaris minor* of Mediterranean in1960s.

Weed flora shifts as a result of imported improved varieties:

- Imported seed lots of improved varieties and foodgrains may bring unwanted weed seed into the country. Change in agronomic practices may also be conductive for the imported weed seed to multiply.
- With the introduction of dwarf wheat in India, *Avena fatua* (Wild oat) dominated the dwarf wheat crop, and
- *Phalaris minor* weed introduced along with dwarf wheat became a major weeed in all the wheat growing areas of the country.

Weed flora shift due to change in crop rotation, sequence and cropping system:

- Differences in plant morphology influence the degree of weed infestation. When a short stature crop is introduced in place of a long stature crop, the weeds suppressed by long stature crop will become dominate in short stature crop.
- A suppressed weed *Celosia aregentea* in sorghum/pearlmillet will be a dominant weed in groundnut, and
- Dominant sedge weeds in lowland rice fields disappear when groundnut replaces the rice
- *The rice-wheat rotation gained more popularity during the past many years, so instead of low water/fertilizer requiring weeds, the infestation of Phalaris minor (Gullidanda/ Sitti) became more prominent as the prevailing growing conditions were favorable for this weed to grow.*

Effect of Crop Rotation On population of Phalaris Minor

Sr. No	Crop Rotation	Phalaris Minor (No./m^2)
1	Rice- wheat (Count for 10 years)*	2350
2	Rice- berseem, Rice- wheat	255
3	Rice- wheat, Rice- cotton, Cotton- wheat*	2125
4	Rice- berseem, Sorghum- wheat	190
5	Rice- potato, Rice- wheat	255
6	Rice- berseem, Rice- berseem, Rice- wheat	28
7	Rice- winter maize, Sorghum- raya, Maize- wheat	18
8	Cotton- wheat (For 4 years)*	38
9	Maize- sun flower, Rice- berseem, Rice- wheat	35
10	Rice- potato, Chilly- potato, Rice- wheat	24
11	Rice- wheat (For 5 years), Chilly- wheat*	2421

Isoproturon was also used in wheat @ 1kg/ha at 30- 35 DAS — Banga et al., (1999)

Shift due to various weed management practices (*Herbicide use):*

Population biotype shift due to long term herbicide use (same type)

Herbicides provides selective kill of one of more types of weeds, whereas, few weed species are partially killed or not killed at all and these dominates with the continuous use of same herbicide group year after year.

Rice :

BUTACHLOR (Continious use 6 years)

Decrease in → *E.Colona* (4 times), *E.Glabrescens* (6)

Increase in → *Monochora viginalis (3)*, *Sphenoclea zeylancia(2.4)*

Wheat :

Phalaris minor → **ISOPROTURON** → Development of resistance

↓ Fenoxaprop p ethyl, Clodinafop propagyl and sulfosulfuron

Phalaris minor controlled

↓

Narrow spectrum weed control causes increase in Rumex spp.

Soyabean - Wheat system:

Previous Weed Spp.	New Emerged Weed spp.	Reason
Echinochloa colona *Elusine indica* *Dactyloctanium aegyptium*	*Celosia argentia* *Cleome viscosa* *Digeria arvensis*	Continuous use of Alachlor and Fluchloralin

Transplanted Rice :

E. crusgali and E. colona

↓ (Continuous use of same group of herbicides)

Ischamum rugosum and *Leptochloa chinensis* emegred as major weed species.

Wheat :

- In1960s, continuous use use of herbicides like 2,4-D, MCPA to control BLW,s in wheat resulted in emergence of grassy weeds becoming the major problem in India and the world

Community shift in response to change in tillage practice:

- *The puddling as well as water stagnation conditions which are pre-requisite for rice are ecologically favorable for* *survival, growth and development of Phalaris minor.*

- Tillage effects weed seed germination rates and efficacy of the weed control methods.
- Thus affecting weed populations.
- Tillage influences soil conditions and the physical location of the weed seed bank thereby influencing dormancy of weed seeds.
- Tillage alone is not that effective a measure to check weeds but when used in combination with varying crop rotations and herbicides can be a powerful tool to throw weed species off balance.

Effect of Management practices on Weed Flora Shift

Management Practice	Selection Pressure exerted	Weedy Traits	Weed Population Shift
Continuous cropping	Simple repetitive agronomic practices	Crop mimicry	+ Broad leaf weeds in broad leaf crops + Grass weeds in cereal crops + Summer weeds in summer crops
Rotational cropping	Diversity in crop species, seeding rates, fertilizers	Competitive ability	+ Species with competitive traits(e.g. Rapid germination and early growth rapid canopy closure, greater height, tillering or branching)
Reduced tillage/stubble retention	Low soil disturbance	Ability to germinate from shallow depths	+ Wind dispersed species + Perennial/biennial species
	Allelopathic effect from crop residue	Tolerance to allelo chemicals	- Species susceptible to crop exudates
Herbicide use	Reliance on single herbicide group	Herbicide resistance genes	+ Species herbicide tolerance
Harvesting	Mechanised harvesting	Avoid seed removal at harvest, Mimicry of seed types (cereals and grass weeds)	+ Early maturing species + Small Seeded

(+) Indicates an increase in abundance (-) Indicates a decline in abundance

FUTURE CONCERNS

- Change to weed species that are difficult to control
- Herbicide resistant biotype

STRATEGIES

- Management of weeds base on entire rotation of locality and not on individual crops
- Study of weed population dynamics with change of rotation and establishment methods
- Integrated weed Management

CONCLUSION

- Current weed management system have led to herbicide resistance and proliferation of crops that mimic weeds.
- Thus the producers and scientists are seeking alternative strategies for weed management, so that weed control does not rely so strongly on herbicides.
- Extensive efficacy data on weed species has been collected but this knowledge has seldom been integrated at cropping system level.
- However utilizing the principles of varying **selection pressure** to keep weed communities off balance and increasing crop competitiveness can reduce weed densities to minimize losses from weeds and inhibit adverse community changes towards difficult to control species or herbicide resistant population.

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Methods of herbicide application


Surface application method


Incorporation after surface application


Blanket application

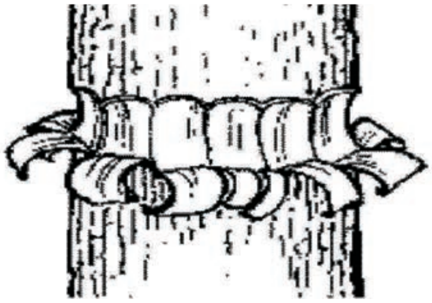

Directed spray


Protected spray


Foliage treatment


Basal bark treatment


Cut stump treatment


Frill and notch method


Tree injector


Spot treatment


Stem injection using a hatchet
and spray bottle


Soil fumigation under sealed plastic cover

Methods of weed control


Deep tillage


Intercropping


Application of solarization plastic


Dry grass mulching


Intercultivation


Tractor drawn weeding


Hand weeding


Power rotary weedng


Black plastic mulch


Growing of herbicide tolerate crops


Puddling by power tiller


Bioherbicide spray

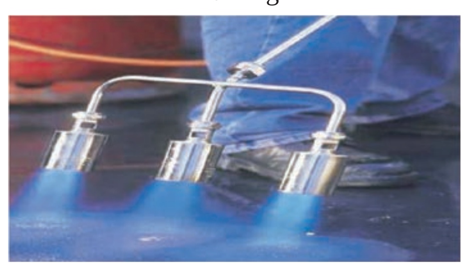

Cono weeder weeding


Dryland weeder


Flaming


Spraying of herbicide


Maxican bittle On Gajargawat

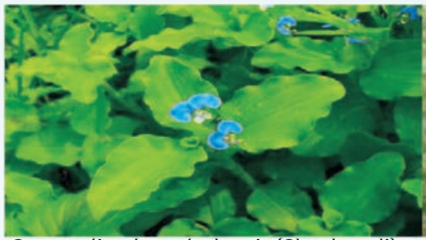

Flame througher (Flaming)

Identification of different weeds

Cynodon dactylon (Dharo)

Cyperus rotundus (Chidho)

Tridax procumbens (Ekdandi)



Commelina benghalensis (Sheshmuli)

Chenopodium album (Chill)

Sorghum halapense (Baru)

Convolvulus arvensis (Chandanvel)

Calotropis gigantea (Akdo)

Eichhornia crassipes (Jalkumbhi)

Parthenium hysterophorus (Gajarghas)

Amaranthus viridis (Tandaljo)

Lantana camara (Gandhati)

Orabanche cernua on Tobacco a (vakumba)

Striga asiatica in sorghum (Agio)

Cuscuta reflexa (Amarvel)

Loranthus longiflorus on mango (Vando)

Trianthema portulacastrum (Satodi)

Digera arvensis (Kanejro)

NAVSARI AGRICULTURAL UNIVERSITY

College of Agriculture
Navsari Agricultural University
Waghai - 394730

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PRACTICAL MANUAL

HORT. 4.4

Production Technology for Ornamental Crops, MAP and Landscaping (1+1)

Department of Horticulture
College of Agriculture
Navsari Agricultural University
Waghai-394 730 (Dangs), Gujarat

Prepared and Compiled By:
Dr. S.A. Aklade , Dr. B. Chakraborty
Dr. M. Sarkar, and Prof. H.A. Prajapati

NAVSARI AGRICULTURAL UNIVERSITY

ICAR

PRACTICAL MANUAL

(As per 5th Dean)

Course No.	:	**Hort : 4.4**
Credits	:	**1+1**
Course Title	:	**Production Technology for Ornamental Crops, MAP and Landscaping**
Semester	:	**4th (Fourth)**
Degree	:	**B.Sc (Hons.) Agri.**
College	:	**CoA, NAU, Waghai**
Department	:	**Horticulture**
Prepared & Compiled by	:	**Dr. S. A. Aklade**
		Dr. Binayak Chakraborty
		Dr. Mangaldeep Sarkar &
		Prof. H. A. Prajapati

Name of Student: ______________________________

Registration No.: ______________________________

Roll No.: ______________________________

Dr. Z. P. Patel
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FOREWORD

January, 2019

(Z. P. Patel)

CERTIFICATE

This is to be certified that Mr./Mrs ____________________________________ (Registration No.:____________________________/Roll No.: ____________) studying in 4th Semester of B.Sc (Hons.) Agri. in College of Agriculture, Navsari Agriculture University, Waghai (Dangs) has satisfactorily carried out all the Practical Exercise in Course No. **Hort: 4.4**; Course Title: **Production Technology for Ornamental Crops, MAP and Landscaping (1+1)** during the year 20___.

Date: / /20____ **Place: Waghai**

Signature
Course Teacher

Signature
External Examiner

HoD (Horticulture)
CoA, NAU, Waghai

Principal
CoA, NAU, Waghai

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EXERCISE – 1
IDENTIFICATION OF ORNAMENTAL PLANTS

OBJECTIVE: Identification of different ornamental plants like trees, shrubs, climbers, palms, etc.

TREES

A tree is a perennial plant having a distinct trunk with a crown at the top.

Uses:

- Beautification: i) Flower: Cassia, Jacaranda, Gulmohar.
  ii) Foliage: *Casuraina*, Kusum, Christmas.
- Wind-breaks: *Casuarina*, Eucalyptus.
- Shade: Rain tree.
- Architecturally: Wall – *Casuarina*, Roof – Rain Tree.
- Medicinal : Margosa, Jamun, *Saraca indica*.
- Protection: Erythrina, Amli.
- Food: Moringa, *Syzynium*, Tamarind, Aonla.
- Fodder: Gliridicia, Subakul, Erythrina.
- Wood: Teak, *Dalbergia sissoo*.
- Pollution Control: Peltophorum, Neem, Spathodia.

Propagation:

- Cutting: Ficus, Erythrina, Glyricidia.
- Root sucker: *Butea monospermum*, Spathodia, *Milintonia hortensis.*
- Layering: *Syzynium*.
- Grafting: Aonla, Citrus.
- Seed: most of the plants.

Classification of Trees:

I. According to flowering:

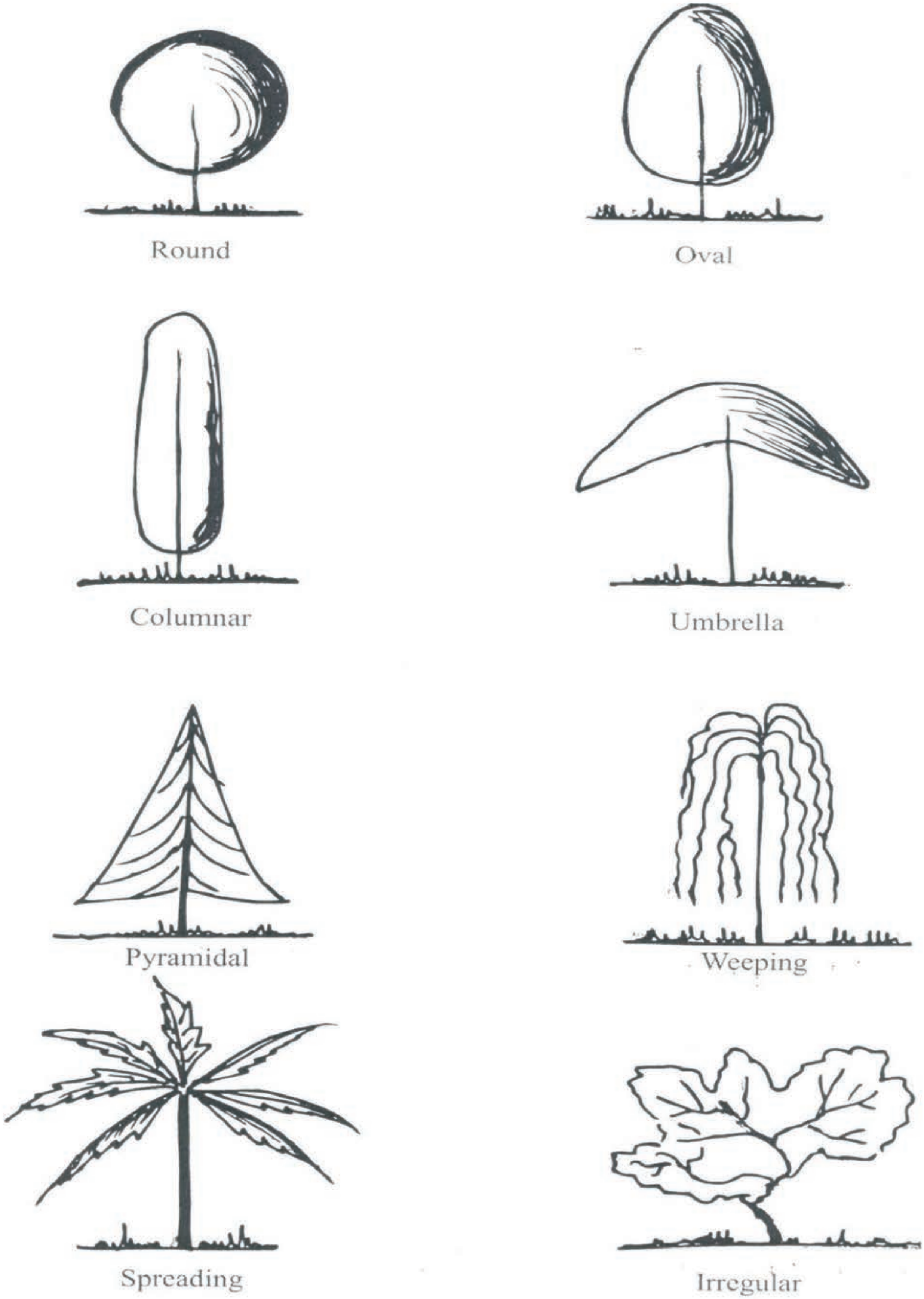
- Flowering: Gulmohar, Peltophorum, Spathodea, Cassia, Bauhinia, Jacaranda, *Erythrina indica*, Largerstroemia, Cordia.
- Foliage: Neem, *Ficus*, Rain tree, Eucalyptus, *Casurina*, Ashok, Teak, Kusum.
- Fruit Bearing: Seedling Mango, Tamarind, Jamun, Mulberry, Palm s.

II. According to height:

- Dwarf: 0.74 to 6m: Plumeria, Cordia, Borsalli, Erythrina, *Ficus panda*, Bauhinia.
- Medium: 6m to 12m: Gulmahor, Acasia, Paltopharum, *Delberzia sisso*.
- Tall: More than 12m: *Casurina*, Deoder, Teak, Silver Oak, Eucalyptus, Parkia.

III. According to shape of canopy:

- Roun :- Mango, *Acassia nilotica*, Peltophorum, Mahudo.
- Oval :- Bakul, Jamun, Ashoka.
- Columnar :- Eucalyptus, *Casuarina*, Silver Oak, Pendula.
- Umbrella :- Rain Tree, Gulmahor, *Cassia nodosa*, Karanj.
- Pyramidal :- Christmas tree, Pines, Deodar.
- Weeping :- Weeping Willow, Bottle, Brush, *Ficus nitida*.
- Spreading :- Palms- Royal, Date, Areca, Fishtail, Coconut, etc.
- Irregular: :- *Butea monosperma* (*Kesudo*).



Different Type of Tree Canopies

Description of Some Important Ornamental Trees

SN	Botanical name (common name)	Family	Flowering season	Flower colour	Remarks
1	*Albizzia lebbek* (Albizzia, Shirish)	Leguminoseae	April-May	Greenish white,	heavy fragrance, Attractive foliage, 16-20 cm long pods
2	*Butea monosperma* (Flame of the Forest, Kesudo)	Leguminosae	Feb -March	Orange, red	Flowers used as dyes, gum is used for tanning
3	*Callistemon lanceolatus* (Bottle brush)	Myrtaceae	Throughout the year	Scarlet red	Drooping / pendulous growth habit, flower resembles bottle cleaning brush
4	*Cassia fistula* (Golden shower, Garmalo, Amaltas)	Leguminosae	February – May	Yellow	Medium sized tree
5	*Delonix regia* (Gulmohar /May flower)	Leguminoseae	March-July	Scarlet, Yellow plus orange	Large deciduous tree, umbrella shaped crown, 12-20 m height
6	*Grevilleae robusta* (Silver oak)	Proteaceae	March-April	Reddish orange	Medium sized tree (25 m), attractive foliage
7	*Peltophorum pterocarpum* (Peltophorum, Copper pod tree)	Leguminoseae	March-April, partially in rainy season	Yellow	Large tree (30 m) spreading crown, road side planting
8	*Plumeria alba - white; Plumeria rubra - pink, red)* (Champa/ Pagoda tree / Temple tree)	Apocynaceae	Summer; *P. alba* -through out year	White or shades of pink, red and yellow	Medium sized deciduous tree
9	*Pongamia pinnata* (Karanj/ Pongamia)	Leguminoseae	May-June	Lilac coloured or pale pink	Moderate sized tree (10-15 m), shining dark green leaves
10	*Ficus bengalensis* (Banyan tree, Vad, Ficus)	Moraceae	-	-	Large, 30 m tall, horizontal spreading
11	*Ficus religiosa* (Pipal)	Moraceae	-	-	Large upright tree, used for shade
12	*Polyalthia longifolia* (Ashok, Asopalav, Mast tree)	Annonaceae	-	-	Tall, conical shaped tree with upright branches and drooping leaves.
13	*Casuarina equisetifolia* (Saru)	-	-	-	Tall tree with needle like leaf, used for avenues, topiary and hedges.

SHRUBS

Shrub is defined as a perennial plant having many woody branches arising from the base, attaining height of about 0.5 to 4 m. and generally having erect or bushy growth.

Shrubs are the main attraction of garden with their handsome foliage, colorful flowers and attractive berries. They are ideally suited for topiary work, formal gardening and landscape designing. Shrub may be planted as single specimen in lawn or they can also be planted as hedge to secure privacy or fencing purpose. A well designed shrubbery border is a source of perennial pleasure. Most of the shrubs required regular pruning to maintain their desired shape.

Utility of shrubs in gardening

- They form part of the framework of the garden and create very pleasing picturesque effect if selected and planted carefully.
- Shrubs act as foundation plants for buildings.
- Variegated shrubs especially with silver or dark grey foliage can also produce pleasing effects if planted in appropriate schemes as they provide most suitable contrasts in the garden.
- Flowering can be seen throughout the year from one or other plant.
- They can be used for hedging, fencing and also for topiary e.g. *Hibiscus*, Divi Divi, *Thevetia, Duranta, etc.*
- They can also be grown as potted plants.

Details of Important Ornamental Shrubs

S.N	***Botanical Name*** **(Common name) Family**	**Description**
1	*Acalypha* sp. Euphorbiaceae	Colourful foliage shrubs used for various purposes of garden decoration. *A. hispida, f*lowers appear in erect or drooping, terminal or auxiliary spikes, called 'cat's tail'. Mostly used as hedge plant. It is propagated from stem cuttings.
2	*Tecoma stans* Bignoniaceae	An erect or rambling shrub growing up to 1.5 to 3.0 m height. Flowers borne in terminal panicles or racemes during summer and rains.
3	*Caesalpinia pulcherrima (*Peacock flower, Sankasur) Fabaceae	It is a beautiful bushy shrub with few prickles. Flowers are orange scarlet in terminal raceme; sepals are red, tinged green. It is propagated by seeds.
4	*Calliandra brevipes* (Powder puff) Fabaceae	Bushy shrub with branches drooping and spreading. Flowers arise in clusters with numerous fine pink stamens. The plants are multiplied from seeds or layers. Flowering seen almost throughout the year.
5	*Cestrum nocturnum* (Night queen, Ratrani) Solanaceae	A large bush with weak branches; leaves are oblong and alternate. Flowers grow in axillary or terminal panicle, creamy white and night scented; Propagated by cutting and layering.
6	*Codiaeum variegatum (*Crotons) Euphorbiaceae	Medium sized shrubs with attractive foliage in multiple colours and spots, suitable for semi shaded and open areas. It is propagated by air-layers and cutting.
7	*Cassia biflora* Leguminosae	3 m tall, bushy, evergreen plant with compound leaves having 10-12 pairs of leaflets. Golden-yellow flowers develop in clusters of auxiliary or terminal raceme and blooming almost throughout the year. Pods are flat. Propagation is by seed.

8	*Duranta plumeri* (Duranta, Pili Mendi) Verbenaceae	A tall, bushy shrub with axillary spines. Branches are 4 angled. Flowers are blue in loose terminal panicles. Fruits are yellow in colour propagation is by cuttings.
9	*Eranthemum bicolor* Acanthaceae	Bushy plant with colourful foliage and 4 lobes, tubular, white flowers at terminal or auxiliary raceme. Plants grow well in rich porous soil. Plant is useful for shady and semi-shady places. Propagation is by terminal cuttings.
10	*Euphorbia pulcherrima* (Christmas flower, Fire ball) Euphorbiaceae	A shrub with cylindrical branches. Leaves are with pink petioles. Flowers appear as clusters on top of the branches. Bracts are crimson red and are showy during winter; propagated from cuttings.
11	*Euphorbia leucocephala* Euphorbiaceae	Medium shrub with cylindrical branches. Leaves turn to white during winter giving beautiful appearance. Flowers are small, white, and arise in leaf axils and terminals. Propagation is by air layering and cuttings.
12	*Tabernaemontana coronaria* (Cape Jasmine, Tagar) Apocynaceae	A very popular shrub. The leaves are simple oblong flowers are white. Single, semi double and double forms are available in terminal or axillary cymes. (Cuttings)
13	*Hamelia patens* Rubiaceae	A handsome perpetual flowering shrub, stem is reddish green, pubescent leaves. It produces numerous tubular flowers all the year round. Propagation is by cutting or air layering.
14	*Hibiscus rosa sinensis* (China rose, Jasood) *Malvaceae*	Tall or medium sized, evergreen shrub with ovate, coarsely toothed leaves and large, solitary, axillary, single or double flowers, having shades of one or two or more colours. Propagated by cuttings.
15	*Ixora singaporensis* *Ixora coccinea* Rubiaceae	Popular and useful flowering shrubs in the garden and almost all the species and varieties flower very freely in the summer and rains. Many types of Ixora produce seeds, but cuttings and layering are the common methods of propagation
16	*Jasminum spp.* (Mogra, Chameli) Oleaceae	Group of shrubs of commercial importance. Leaves are opposite or alternate; flowers are in terminal or auxiliary corymbs and flowering seen for 5-6 months in summer and rains. Large-scale propagation is done by cuttings.
17	*Jatropha spp.* (Coral bush, Ratanjyot) Euphorbiaceae	A perpetual flowering shrub; flowers are pink and red with yellow stamens. Propagation is by stem cuttings.
18	*Lantana camara* Verbenaceae	Prickly stemmed bushy plants of half to two meters height. Leaves are opposite, ovate or oblong, toothed, coarse. Flower colours range from yellow, bright red, white etc. (cuttings or seed)
19	*Nerium oleander* (Karan) Apocynaceae	A evergreen erect shrub, leaves mostly in whorls of three, lanceolate, flowers may be single or double in terminal panicles, slightly fragrant. Pink, white, rosy red colour flowers are available. Propagated by stem cuttings.
20	*Polyscia filicifolia / Aralia filicifolia)* (Arelia) Araliaceae	An erect glabrous shrub. The stem and leaf stalks are with various colours. There are usually 3 leaflets, which are roundish or reniform shaped.

CLIMBERS

Climbers: Botanically, it is plants which have special structures like thorns, tendrils, rootlets, or modified leaf stalk, etc. to climb over supports. E.g. *Antigonon, Monstera deliciosa,* etc.

- **Hook like thorn**: - Bougainvillea, Asparagus.
- **Tendril: -** *Antigonon leptopus*, Bignonia.
- **Rootlets: -** *Ficus repens*, Philodendron, Syngonium, *Tecoma grandiflora*, Monstera, Money Plant (Pothos).
- **Modified leaf stalk or tips: -** Glory lily.

Creepers: Plants which unable to climb vertically on their own because of their weak stems. E.g. *Wedelia, Tecoma radicans.* etc.

Use of Climbers & Creepers:

- Covering the wall, fence, beautify the dry seen.
- It is use to give protection as a fence.
- It can be trained as a specimen on lawn with constructive special structure or with their own stem.
- Trained on gate over arches, or path conservatory. e.g. Juie, Madhumalti, Allmanda, Jacquimontia, Lasoon vel.
- Some of the climbers good for roof garden. e.g. Veronica, All manda.
- Used as an indoor plant/house plant. e.g. Pathos, Asparagus.
- Use for cut foliage, scented flowering for garland preparation. e.g. Money plant, Asparagus, Mogro, Juie.

Propagation:

- Seeds: Antigonan, Asparagus, Star Ipomea, Morning glory, Railway creeper, Wood rose creeper.
- Cutting: Most of the perennial climber.
- Air layering: Bougainvillea, Rose.
- Root suckers: Asparagus, Clerodendron, Lasoon vel, Allamanda.
- Grafting: Petrea, Allamanda.

Popular Climbers and Creepers Used in Landscape Gardening

SN	Botanical name (common name) Family	Description
1.	*Adenocalymma callisa* (Garlic vine) Bignoniaceae	An evergreen plant with dense foliage. Flowers appear on large axillary panicles. Leaves are leathery producing an odor of garlic. Flowers are funnel shaped and mauve in color with 5 petals. Flowers during October to February and also in summer. Propagation is by simple layering.
2.	*Antigonon leptopus* (Coral vine) Polygonaceae	A tuberous rooted very quick growing climber. Stems are slender, green. Grown for the purpose of screening. Honey bees are attracted, propagation is by simple layering.

3.	*Allamanda violacea* *(*Allamanda) Apocyanaceae	A slender growing climber with 3-4 leaves / node. Flowers are produced in terminal cymes, large showy and purple in color. Propagation is by cutting and layers. In *Allamanda cathartica* flowers are large, yellow and appear during summer and rains. Corolla tube is long and the throat is striped brown.
4.	*Asparagus plumosus* (Asparagus) Liliaceae	Fine foliage climber with Flowers are small, white and with red berries. Roots are non-tuberous but long and fleshy cladodes are arranged in a horizontal plane and are numerous, 8-16 in a fascicle. It is propagated by seeds.
5.	*Bignonia venusta* Syn: *Pyrostegia venusta* (Flame vine) Bignoniaceae	It is a deciduous climber growing by means of its tendrils. Leaflets are ovate oblong. Flowers are golden colored, many drooping on corymbose cymes. It is a slow growing creeper propagated by layers.
6.	*Clitoria ternatia* Leguminoceae	It is an annual twining climber, leaves pinnately compound flowers are solitary, blue or white, and pods are long. Propagated by seeds. Ideal climbers for low trellis.
7.	*Tecoma jasminoides* Bignoniaceae	It is a handsome flowering climber. Corolla is tubular and companulate; white or rosy pink flowers and the color is deeper at the throat. Propagated by cuttings.
8.	*Ipomoea palmatae* (Railway creeper) Convolvulaceae	A perennial vigorous climber. Flowers are purple, the corolla is campanula ate, the color is deeper in the throat, used for screening purposes. Propagation is by cuttings in sand media.
9.	*Monstera deliciosa* (Australian pineapple) Araceae	A large foliage climber, stem is strong and fibrous, clasping the support by means of long and thick aerial shoots arising from the node. The leaves are large, 1-2.5 feet long, oblong and broad, thick and lathery, strongly scented when the fruits mature. Thrives in shade and semi shade. Propagated by cuttings.
10.	*Petrea volublis* (Purple wreath) Verbanaceae	A woody climber with grayish bark. Many flowers on a long dropping axillary raceme; bluish in color. Flowers are star shaped and appear during summer. Propagated by layers and cuttings.
11.	*Passiflora edulis* (Passion fruit) Passifloraceae	It is a strong woody climber. The flowers are solitary, terminal or auxiliary. 5 petals, the petals are often tinted with purple.
12.	*Quisqualis indica* (Rangoon creeper) Combretaceae	A large and vigorous climber. The flowers are initially white, turn pink and finally it becomes red. Numerous bunches of drooping white, pink or red with slightly fragrant are produced during summer and rains. Propagated by cuttings.
13.	*Scindapsus aureus* (Money plant) Araceae	A tall and much branched climber. Arial roots arise from the nodes. Foliage is bright green with numerous irregular golden lines or paths.

PALMS & CYCADS

Family: **Palms:** Palmaceae/ Areaceae **Cycads:** Cycadaceae

Palm: is an un-branched evergreen tree of tropical and warm regions, with a crown of very long feathered or fan-shaped leaves, and typically having old leaf scars forming a regular pattern on the trunk.

Use of palms in landscape garden:

1. Palms are well suited as single specimens in lawn (eg. *Areca triandra*).
2. Palms are excellent specimens for avenue planting in the gardens (eg. *Roystonea regia*).
3. They are also suitable for decoration of conservatories, verandahs, stair-cases, for indoor decorations as potted plants.

Some Attractive Palms & Cycads for the Garden

SN	Name	B.N	Description
1	Traveller's Tree or Traveller's palm	*Ravenala madagascariensis*	It is not a true palm (family Arecaceae) but a member of the bird-of-paradise family, Strelitziaceae. It has been given the name "traveler's palm" because the sheaths of the stems hold rainwater, which can be used as an emergency drinking supply, especially for the traveler.
2	Fishtail palms	*Caryota* spp. *C. cumingii*	They are often known as fishtail palms because of the shape of their leaves.
3	Foxtail palm	*Wodyetia bifurcata*	Flowering palm. Attractive palm with long (2-3m.) plumose leaves (hence the name 'Foxtail'), and up to 10 m tall with a grey trunk. It produces large (about the size of a duck egg) orange fruit.
4	Rhapis *(Lady palm / Rattan palm)*	*Rhapis excelsa*	*Rhapis excelsa* also known as Broadleaf Lady Palm is a species of fan palm. *Rhapis*, meaning "needle"; and the species name is Latin for "tall", an ironic name choice as *R. excelsa* is not the tallest in the genus.
5	Royal palms *(Bottle palm)*	*Roystonea regia / Oreodoxa regia / Roystonea ventricosa*	*Roystonea* is a genus of large, unarmed, single-stemmed palms with pinnate leaves. The large stature and striking appearance of a *Roystonea* palm makes it a notable aspect of the landscape.
6	Livistona palm (Chinese palm)	*Livistona spp.*	They are fan palms, the leaves with an armed petiole terminating in a rounded, costapalmate fan of numerous leaflets.
7	Areca palm	*Areca lutescens / Dypsis lutescens*	*D. lutescens* is a small to medium-sized palm, growing to a height of 6 to 12 meters. It has multiple stems emerging from the base. The leaves are arched, 2-3 m long, and pinnate, with 40-60 pairs of leaflets. It produces offsets, and these can be cut off, when mature enough, as a propagation method.
#	**Cycads**		
1	*Cycas*	*Cycas revoluta*	It is a plant native to southern Japan. Though often known by the common name of king sago palm, or just sago palm, it is not a palm at all, but a cycad. This very symmetrical plant supports a crown of shiny, dark green

			leaves on a thick shaggy trunk that is typically about 20 cm (7.9 in) in diameter, sometimes wider. The trunk is very low to subterranean in young plants, but lengthens above ground with age. It can grow into very old specimens with 6–7 m (over 20 feet) of trunk; however, the plant is very slow-growing and requires about 50–100 years to achieve this height. Trunks can branch multiple times, thus producing multiple heads of leaves.

BULBOUS PLANTS

- The term, 'bulbous plants' refers to all seasonal plants with underground modified stems containing stored food for the development of the seasonal aerial shoots of stems, leaves and flowers.
- Besides bulbs, this includes corms, rhizomes, tubers and fascicled roots. Bulbous plants are valued for their flowers and foliage and are classified as below.
  - **Tubers** : Dahlia, Asparagus, Glorilily etc.
  - **Rhizome** : Caladium, cana etc.
  - **Bulb** : Amaryllis, Spider lily, Tuberose, crinum lily.
  - **Corms** : Gladiolus, Iris

Uses of Bulbous Plants

- Bedding plant — Gladiolus, Amaryllis, Tuberose.
- Boarder — Spider lily.
- Hanging basket — Asparagus, Begonia, Zephyranthes.
- Rockery — Tuberose, Spider lily, Foot-ball lily etc.
- Cut flower — Gladiolus, Tuberose, Lilium, Iris, Tulip, Spider lily.
- Medicinal use — Asparagus, Glory lily.
- Pot plant — Dwarf Cana, Gladiolus, Dahlia.

Description of Important Bulbous Plants

SN	Common Name	Botanical name & Family	Description
1.	Blue African lily	*Agapanthus companulatus* F: Liliaceae	Produces umbel from March to June, containing 10 – 30 blue flowers with funnel shaped, suitable of 1000 – 2000m above MSL, propagated by offsets.
2.	Cannas	*Canna indica* F: Scitaminae	Produces large trusses of flowers of larger size, based on height, classified as dwarfs, medium and tall.
3.	Gladiolus	*Gladiolus sp* F: Iridaceae	A popular cut flower, producing single or double spikes, propagated through corms or seeds
4.	Day lily	*Hemerocallis* F: Liliaceae	They bear single or double large and attractive flowers on tall scapes
5.	The garden amaryllis or Trumpet lily	*Hippeastrum* F:Amaryllidaceae	Spectacular flowers, having various shades of bright colour
6.	Dahlia	*Dahlia sp.* F: Compositae	Most gorgeously coloured, free blooming, available in all colours except blue.

FERNS & CONIFERS

Ferns: Ferns are a flowerless plant which has feathery or leafy fronds and reproduces by spores released from the undersides of the fronds. Ferns have a vascular system for the transport of water and nutrients.

Description of Important Ferns & Conifers

	Ferns (Family: Filices)		Conifers (Family: Conifereae)	
SN	**Name**	**B.N**	**Name**	**B.N**
1	Maiden hair fern	*Adiantum tenerum*	Indian fir	*Pinus deodora*
2	Asplenium	*Asplenium nidus*	Thuja	*Thuja orientalis*
3	Gymnogramma	*Gymnogramma* spp	Juniper	*Juniperus communis*
4	Trichomanes	*Trichomanes* spp.	Cypress	*Cypressus* spp.
5	Glecichenia	*Gleichenia* spp.	Aurocaria (Christmas tree)	*Aurocaria excelsa*
6	Sword fern	*Naphrolepsis exaltata*	Pine	*Pinus longifolia*
7	Pteris	*Pteris cretica*	Casuarina (Sharu)	*Casuariana equisetifolia*

AQUATIC PLANTS

	Ferns (Family: Nymphaceae)	
SN	**Name**	**B.N**
1	Water lily (white)	*Nymphaea nouchali*
2	Water lily (Rose)	*Nymphaea rubra*
3	Water lily (Blue)	*Nymphaea stellata*
4	Lotus	*Nelumbium speciosum*
5	Giant lotus	*Victoria amazonica*

CACTUS AND SUCCULENTS

- These are group of plants which have special structures to store water in thick fleshy leaves or stems. Their leaves are fleshy with plenty of water-holding tissues, often reduced in size, covered with a thick epidermis with only a few stomata and are often coated with a whitish or blue wax or wooly hairs.
- They thrive best in sunny situations and are light loving.
- They need little care except when actively growing.
- All the cacti are succulents on account of storing water but all the succulents are not cacti. There is a clear cut distinction between both. Cactus is characterized by the presence of areoles sp., which often looks like woolly cushions carrying spines, hairs and the flowers arise from or near the areoles. The spines in cactus are modified leaves which provide shade against scorching sun and help in conservation of moisture besides protecting against birds and beasts.
- All the cacti are succulents on account of slowing water but all the succulents are not cacti. The cacti are one type of succulents which are exclusively belonging to the family ‘Cactaceae’. They are perennials, bearing spine cushions called ‘aeroles’. Most of the cacti do not have leaves but the succulents have leaves. The cacti usually bloom annually and are beautiful and large.
- Like any other plant, cacti can be raised from seeds but the process is very slow. Hence, the common practice is to grow them through vegetative buds. The container for cacti is filled with about 10 cm of gravel and above that a thin layer of sand is spread to provide drainage. The best soil mixture consists of sandy loam, little cowdung manure and some broken bricks. Watering by sprinkling should be done once or twice in a week. Repotting is necessary with fresh soil once in two or three years, usually in the same containers, since the plants grow very slowly.

- Cactus and succulents are very popular amongst gardeners, amateurs and hobbyists who are used to adorn sunny situations of gardens, houses, window sides and rock gardens.

E.g. of Cactus: *Euphorbia,* Cephalocereus, *Echinocactus, Echinocereus, Echinopsis, Epiphyllum,etc.*

E.g. of Succulents: *Agave Americana, Aloe, Bryophyllum, Furcraea watsoniana, Echeverias, Kalanchoe sp. Pedilanthus sp., Sansevieria zeylanica, etc.*

Student Activities:

(i) Prepare a herbarium of ornamental trees, shrubs and climbers.

(ii) Collect the seeds of various ornamental trees, shrubs and climbers present in our campus.

(iii) Give examples of following present in our campus

1) Flowering trees, shrubs and climbers.
2) Foliage shrubs, climbers and shade trees.
3) Trees, shrubs and climbers having fragrant flowers.
4) Cactus & Succulents.
5) Bulbous plants.
6) Palms & Ferns

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EXERCISE – 2
IDENTIFICATION OF SEASONAL ANNUALS

OBJECTIVE: Identification of different annual flowering plants.

Introduction:

Annuals belong to the class of plants, which attain their full growth from seed, flower and die in one year or one season. Annuals seeds are sown in nursery beds and seedlings are then transplanted. Flowering annual plants widely vary in form, habit of growth, flower colour and flower size. They beautify the surroundings and exhibit a good show of blooms at very low cost and labour. They bring mobility in the look of garden through seasonal changes. These annuals are grown for various situations and purposes in the garden like for pots, hanging baskets, beds, edging, rock garden, shady situation, herbaceous border or in window boxes. The planting of annuals in the border of plot is called as herbaceous border.

According to their growing season annuals may be put under three groups:

1) Rainy season annuals:

They are sown before rains (May-July) and flowers during the monsoon season. They can withstand in heavy rains and high humidity than other annuals. Some rainy season annuals emerge automatically with first rains and flowers during monsoon e. g. Balsam, Cosmos, Zinnia, etc.

2) Winter season annuals:

They are able to tolerate low temperature and thrive and bloom best during winter. Large numbers of flowering annuals are winter season annuals and produces very spectacular view with the riot of colour. Seeds are sown during September- November.

3) Summer season annuals:

They require high temperature and long photoperiod for blooming. They are sown during January-February and produce flowers during March- May.

<u>List of Important Flowering Annuals</u>

SN	*Botanical name* (Common name) & family	Height (cm)	Flower colour	Growing season W-Winter S-Summer R-Rainy	Description
1.	*Ageratum sp.* (Floss flower) Compositae	40-50	White, blue	W	Full blooming, useful for edging, massing in beds and for mixed borders
2.	*Althaea rosea* (Hollyhock) Malvaceae	120-180	White, crimson, pink, yellow, red	W	Large single or double flowers; useful for screens, borders and for background, suited to hills.
3.	*Amaranthus sp.* (Love-lies-bleeding) Amaranthaceae	100-150	Crimson, purple, yellow	R-W-S	Foliage and blooms are different coloured, Foliage types: A. tricolor, *A. salicifoliu*, *A. melancholius ruber*, *A. caudatus*
4.	*Antirrhinum majus* (Snap-dragon) Scrophulariaceae	15-120	White, yellow, pink, rose.	W	For bedding, borders, pots, good cut flower.

5.	*Callistephus chinensis* (China aster) Compositae	40-50	White, pink, blue	R-W-S	Suited for borders, bedding and pot. Good cut flower.
6.	*Coreopsis spp.* (Tick seed) Compositae	30-90	Yellow brown or Crimson brown	R-W-S	For borders and flower beds, flowers single or double; suitable for flower arrangement.
7.	*Celosia spp.* (Cock's comb) Amaranthaceae	15-100	Red, crimson, yellow, orange, white	R-W-S	Suited for borders, beds, pots, less care and maintenance.
8.	*Cosmos bipinnatus, C. sulphureus* (Cosmea, Cosmos) Compositae	90-150	White, crimson, rose, yellow, Magenta & purple	R-W-S	Popular annual for flower beds, *C. bipinnatus* is ideal for winter while *C. sulphureus* can be grown throughout the year.
9.	*Dianthus barbatus* (Sweet William), *D. chinensis* (Dianthus or Pink) Caryophyllaceae	30-45	Crimson, white, red, pink, yellow	W	Useful for pots, beds and borders and as cut flower for vase decoration, *D. barbatus* have light scented flowers.
10.	*Gaillardia pulchella* (Blanket flower) Compositae	50-60	Yellow, orange, bronze, red	R-W-S	Suitable for beds, borders and as loose flowers; single or double flowers. Good commercial flower, flowers throughout the year.
11.	*Gomphrena globosa* (Globe amaranthus or Bachelor's button) Amaranthaceae	60-75	Purple, white pink, orange	R-W-S	Suitable for beds, borders and as cut flowers; Flowers throughout the year.
12.	*Helianthus annus* (Sunflower) Compositae	60-150	Yellow, brown, orange	R-W-S	Staking is essential for tall and unbranched varieties; seeds can be directly sown in the beds.
13.	*Helichrysum bracteatum* (Straw flower) Compositae	70-90	yellow	W	Suited for pots and borders, suitable for drying hence called as everlasting flower.
14.	*Impatiens balsamina* (Balsam) Balsaminaceae	60-75	white, orange, red, pink violet	R-W-S	Suited for borders, beds, very delicate and needs care, bear flowers in the leaf axils of the branches.
15.	*Kochia spp.* Chenopodiaceae	60-75	-	S	Suited for borders and pots, attractive lush green foliage, loves open sunny situations.
16.	*Petunia hybrida* Solanaceae	50-75	Red, blue, white, pink, violet	W	Suited for flower beds, mixed borders, pot plants, window boxes and hanging baskets.

17.	*Phlox drummondii* Polemoniaceae	30-50	White, blue, pink, red, violet	W	Suited for beds, pots, rockery.
18.	*Papaver rhoeas* (Poppy) Papaveraceae.	60-75	Red, pink, white, yellow	W	Suitable for flower beds and pots, early flowering, prefers sunny situation and light soil.
19.	*Tagetes erecta* (African marigold) Compositae	60-120	Yellow, orange	R-W-S	Tall and erect growing annuals, single or double flowers, effective in beds and mixed borders. Major commercial flower.
20.	*Tagetes patula* (French marigold) Compositae	30-40	Yellow, orange, red	R-W-S	Suited for pots, beds and borders
21.	*Tithonia speciosa* (Mexican sunflower) Compositae	70-150	Orange, scarlet	S-R	Reddish orange flowers on long stalks, can be grown throughout the year, suitable for borders and beds
22.	*Zinnia elegans* Compositeae	75-90	White, orange, red, pink, yellow, violet	R-W-S	Hardy plant, flowers in profusion for a long period, single or double flowers borne on long stalks. Attractive in borders and beds, less care needed.
23.	*Zinnia linearis* Compositeae	20-30	Golden orange, white	R-W-S	Hardy flowering perennial, linear leaves, beautiful small golden orange flowers, useful for low bed, edging, hanging baskets and rockeries.

Student Activities:

1) Prepare a herbarium of flowering annuals.
2) Collect the seeds of various flowering annuals present in our campus.
3) Classify flowering annuals as per season, plant height, family and colour.

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EXERCISE – 3
IDENTIFICATION OF MEDICINAL AND AROMATIC PLANTS

OBJECTIVE: Identification of major & minor medicinal and aromatic plants.

A) MEDICINAL PLANTS

Medicinal plants are those plants, which are rich in secondary metabolites and are potential source of drugs. The secondary metabolite includes alkaloids, glucosides, coumarins, flavonoids and steroids.

Metabolites : A metabolite is any substance that is produced during metabolism or that takes part in metabolism

Alkaloids : Large group of nitrogenous base elements used as drugs

Glucosides : The compound, which give glucose and other product

Coumarins : Nutritive substance

Flavonoides : Protective compound, which have flavour.

Steroids : A group of organic compound with 4 C ring includes some hormone and physiological substances.

1. Isabgol

Botanical name : *Plantago ovata*

Family : Plantaginaceae

Method of propagation : Seeds

Use: Seeds are used in herbs. It is diuretic, useful in constipation. Seeds have cooling and demulcent effect. Cure dysentery and diarrhoea.

Description: Almost stem less, 30-40 cms in height covered with dense or short hairy growth, leaves are 8 - 15 cm long, very narrow, flower are minute, seeds are 8 mm long, seeds are boat shape.

2. Aswagandha

Botanical name : *Witthania somnifera*

Family : Solanaceae

Method of propagation : Seeds

Use: The drugs consist of dried roots of the plants. Useful in sexual and general weakness. It is diuretic, means it promotes urination. Root powder is applied locally on ulcers.

Description: It is small or middle size shrub up to 1.5 meter in height. Stem and branches covered with minutes star shape hair. Leaves are 10 cms long, hairy like, branches, pale green flowers, small flowers (1 cm), fruits are 6 mm in diameter.

3. Liquorice (*jethimadh*)

Botanical name : *Glycyrrhiza glabra. L*

Family : Leguminaceae

Method of propagation : Seeds

Use: The dried roots and underground stems of these plants constitute the drug. It is useful in cough, promotes urination and helps in antibiotics and antibacterial activity. Due to its taste, demulcent property, it is used in making syrups and masking bitter taste of medicine. Useful in gastric and ulcer.

Description: It is a tall erect perennial herb or under shrub about 1 to 2 meters height. Root system is highly branched and consists of a short tap root with large number of rhizomes. Flowers violet in colour & fruit 1 - 2 cm long.

4. Guggal

Botanical name : *Commiphora wightii* & Commiphora mukal
Family : Burseraceae
Method of propagation : By stem cutting and air layering
Use: Gums having herb value. It controls cholesterol blood. Increase milk, excites uterus and useful in ladies treatments.
Description: It is shrub reaching height up to 3 to 4 m, branches are naughty, aromatic and at the end sharp spine. Leaves are alternate 1 to 5 cm long and 0.5 to 2 - 5 cm broad. Plants having bisexual and male flower.

5. Sarpagandha

Botanical name : *Rauvolfia serpentina*
Family : Apocynaceae
Method of propagation : Seeds, Roots and Stem cutting
Use: Roots are used in medicine. Used in hypertension. As sedative used in asthma useful in painful delivery of child besides controlling high blood pressure.
Description : It is a erect evergreen perennial plant growing up to 0.75 m in height, leaves are simple long elliptical. Bears many flowers of white or pink colour. The root system consists of a prominent tuberous short tap root up to 6 cm diameter.

6. Senna

Botanical name : *Cassia angustifolia*
Family : Leguminosae/ Fabaceae
Method of propagation : Seeds
Use: Leaves and pods are well known for purgative medicines all over the world.
Description: It is perennial, bushy plant; height is 0.7 to 1 meter. Leaves are narrow glabrous leaflets. The flowers are brilliant yellow colour. Pods are black; thin contain five to seven dark brown seeds. All parts contain senosides. Leaves and pods contain maximum.

7. Kalmegh (Kariyatu)

Botanical name : *Andrographis paniculata*
Family : Acanthaceae
Method of propagation : Seeds
Use: It is a bitter tonic, useful in curing fever, worms dysentery, general weakness excessive gas formation in stomach. It is useful in children suffering from liver and digestion complaint. Drug consists of all parts of plant.
Description: As erect branch annual herb. Branches are sharply four angled. Flowers are rose coloured one cm long.

8. Ardusi

Botanical name : *Adhatoda adusa*
Family : Acanthaceae
Method of propagation : Stem cutting and seeds
Use: The drug comprises the fresh and dried leaves of the plants. Leaves contain alkaloid vaccine & essential elements. Leaves & roots are used in cough and asthma.
Description: A tall much branched, dense, evergreen shrub with large leaves, flowers in dense short spikes white in colour with few purplish, markings fruit capsular and seeded.

9. Baheda

Botanical name : *Terminalia bellirica*
Family : Combretaceae
Method of propagation : Seeds

Use: Fruits are useful in stomach disorder like diarrhoea. It is also given as a brain tonic, useful in piles leprosy and fever. Half ripe fruit is purgative but ripe fruit has the opposite property. It is used for making trifala churna.

Description: It is large tree, leaves are large (10 - 15 cm). Flowers are small, pale green, bad smelling. Fruits are 2 - 3 cm long brownish cover with hairs.

10. Harde

Botanical name : *Terminalia chebula*
Family : Combreaceae
Method of propagation : Seeds

Use: It is used in making trifala churna. It is digestive and mild laxative.

Description: It is middle size to large size. Leaves are 10 - 20 cm long ovate. Not crowded at the end by branches. Leaves are opposite and pair, flowers is dull white in spite at the end of branches. Fruits are 2 to 4 cm long.

11. Aonla

Botanical name : *Emblica officinalis*
Family : Euphorbiacea
Method of propagation : Patch budding

Use: It is very rich source of Vita-C (600-800 mg/100g pulp) therefore regarded very important for medicinal value in Ayurvedics. It is an important ingredient of Triphla and Chayanpras. It is useful in haemorrhages, diarrhea, dysentery, anaemia, jaundice and cough. Fruits are commonly used as preserve pickle, candy, jelly and jam. It is also used in preparation of inks, hair dyes and hair oil. It is great health and vitality restorer.

Description: It is a tall tree, quite hardy, prolific bearer, deciduous tree. Phyllanthoid branching habit with two types of shoot determinate and indeterminate. The leaves are simple 1 to 2 cm long. Flowers are borne in the axils of the leaves. Fruits are capsular.

12. Stevia

Botanical name : *Stevia rebaudiana*
Family : Asteraceae
Uses : Calorie-free sweetener, reduces elevated blood pressure and a sugar substitute for diabetic patients.

Description: The plant is a slender, perennial herb growing up to a height of 60 to 70 cm. For diabetic's people, sugar obtained from stevia is considered to be the best alternate source.

13. Asparagus (S*atavari***)**

Botanical name : *Aspargus sativus*
Family : Liliaceae
Method of propagation : By seed and root tuber

Use : It is demulcent aphrodisiac, energy tonic for maintenance of body, increase coolness, increase milk, useful for curing wounds, useful in acidity and weakness.

Description: It is perennial plant having 1 to 2 m. tall. It is grown for soft tender part root. Roots are useful for medicinal purpose. 1 to 2 m height (tall)

14. Aloe

Botanical name : *Aloe barbadensis*
Family : Liliaceae
Method of propagation : By sucker

Use: It is antihelminthic, purgative, stomach cure, constipation, use in cough and nervous system diseases. It is also used in improving fertility and also use in hair problem. It is use for making Shampoo, cream etc.

Description: Plant height is 50 - 60 cm; Leaves are succulent and spine on leaf blade. They are perennial in nature. Flower stocks arise from centre of the leaves. Flowers are orange or pink in colour.

15. Belladonna

Botanical name : *Atropa belladonna* L.
Family : Solanaceae
Uses : Drugs , Belladonna has been used in herbal medicine for centuries as a pain reliever, muscle relaxer, and anti-inflammatory and to treat menstrual problems, peptic ulcer disease, histaminic reaction, and motion sickness

Description: Belladonna is an erect, herbaceous plant, 150 cm high, with a long, cylindrical, branched, fleshy, creeping, perennial root.

16. Ocimum (*Tulsi*)

Botanical name : *Ocimum gratissimum* L.
Family : Labiatae
Uses : Cosmetics, Drugs, flavoring & perfumery

Description: Ocimum is a tall, many-branched and perennial aromatic shrub. The stem is erect, green with short hairs and attains a height of1.25 to 2 m. The leaves are ovate, coarsely crenate serrate, pubescent on both surfacesThe flowers are white to pale yellow in colour.

17. Dioscorea

Botanical name : *Dioscorea composite* L.
Family : Dioscoreoceae
Uses : Cosmetics, Drugs, flavoring

Description: The plant is dioeciously in nature, a robust climber twining to the left. The branches are thick and it produces yellow, compact tubers at a shallow depth. The leaves are petiolate and spirally disposed on the stem.

18 . Steroid -bearing Solanum

Botanical name : *Solanum viarum*
Family : Solanaceae
Uses : Drugs

Description: The crop is a stout, branched, woody shrub attaining a height of 0.75 to 1.5 m. The stem has spines, the leaves are ovate to lobed with spines on both the surfaces, the flowers we hermophrodite borne on axillary cluster

B) AROMATIC PLANTS

Aromatic plants are defined as 'those plants which possess essential oil in them'. This essential oil is the odoriferous, volatile, constituents of the aromatic plants. They are mainly complex mixture of acyclic and or cyclic monoterpenoids. These terpenoids are basically secondary metabolites and they have no apparent function in the plants primary metabolism. The essential oils are used in perfumery, cosmetics and pharmaceutical industries where as the essential oils obtained from spices and condiments which impart the flavour and improve the taste of the food are used in several flavouring industries.

1. Lemon grass

Botanical name : *Cymbopogon fIexuosus*
Family : Gramineae
Methods of propagation : Seeds and by old clumps

Uses: Preparation for á- lonone. Used in flavours, cosmetics and perfumes and â-lonone are used in synthetic vitamin A. Lemongrass is used for treating digestive tracts, stomachache, high blood pressure, vomiting, cough, achy joints (rheumatism), fever, the common cold, and exhaustion. It is also used to kill germs and as a mild astringent. Lemongrass oil, used as a pesticide and preservative.

Description: Grass comes to harvest 90 days after planting and subsequently it is harvested 50 - 55 days interval. Grass is cut 10 cm above the ground level, 5 - 6 cuttings are taken in a year.

2. Citronella grass

Botanical name : *Cymbopogon winteriness* (Java)
Family : Gramineae
Methods of propagation : Rooted slips in April- May

Uses: Oils as bactericidal, insect repellent and medicinal use oil used for scenting soaps and detergents. Oil recovery 1-1.2% according to the dry bases. Major constituent in oil is citral (80 %). Used in perfumery and cosmetic.

Description: It is a moisture loving plant with sandy loam soil is most suitable. This grass can be grown in natural soil. First cutting may be ready after 4 - 5 months after planting and next cuttings are taken at the two months intervals where atmospheric humidity is high.

3. Vetiver (*khas*)

Botanical name : *Vetiveria zizanioides*
Family : Gramineae
Methods of propagation : Slips and tillers (June - July)

Uses: It is used in making vetiver oil or soap making, after extraction of the oil from the roots. Roots are used for making mats, screen, pillow and mattresses. Roots are used in pharmaceuticals and Ayurvedic . Oil is light yellow and contains 65 - 75 % vetiver oil.

Description: It is a perennial grass. Plant height (1-1.8 meters). Root portion is branching type, spongy aromatic and fine rootlets. It grows in large clumps, leaves are long, erect and narrow and nonaromatic andup to 1 meter in length.

4. Palmarosa (*Rosha, Tikhadi*)

Botanical name : *Cymbopogan martinii*
Family : Poaceae/ Gramineae
Method of Propagation : Through seeds, rooted cutting, slips
Uses : Essential oil for soaps, cosmetics, tobacco blending and perfume industries

Description: The plant is perennial, sweet scented grass with 1.5-2.5 M height.

5. Geranium

Botanical name : *Pelargonium graveolens* L.
Family : Geraniaceae
Methods of propagation : Through cuttings
Uses : Essential oil, Perfumery

Description: Small much branched perennial herb of about 1.3 m height and naturally forming a dense spreading bush. Fruit is long and pointed but normally without seed.

6. Mints

* Japanese mint

Botanical name : *Mentha arvensis*

Family : Labiateae

Methods of propagation : Suckers

* Common mint

Botanical name : *Mentha spicata*

Family : Labiateae

Methods of propagation : Cuttings

Uses : Mentha oil, after steam distillation is extracted which is used in manufacture of menthol

Description: Suckers are planted 75 x 15 cms distance. Suckers are cuts into 10 -12 cm. in length and then planted.

7. Davana

Botanical name : *Artemisia pallens* Wall

Family : Asteraceae

Methods of propagation : Through seeds

Uses : Essential oil, Cosmetic, Drugs, Perfumery, flavouring bakery products like cakes, pastries and beverages etc.

Description: it is delicate, erect and branched annual herb 45-60 cm tall, leaves are alternate, florets in center and yellow glabrous.

8. Rose

Botanical name : *Rosa damascana*

Family : Rosaceae

Methods of propagation : Cutting, air layering, T budding and root division

Uses: It is used for production of oil, Rose attar for commercial purpose, rose water, gulkand. The yield of oil is around 0.0045 % (fresh weight bases).

Description: It is perennial, hardy shrub with long life span of 20 - 30 years under cultivation. It grows to a height of 2.5 to 3 meters. Leaf is compound type with 5 - 7 leaflets. Flowers are sweet scented, pink, red or sometimes white, striped in colours

9. Jasmine (*Mogra*)

Botanical name : *Jasminum sambac*

Family : Oleaceae

Methods of propagation : Stem cutting, Root cutting, Layers and air layers.

Uses : Cultivated for extraction of perfumes. Also used in gardens as a hedge or in borders. Concrete recovery 0.14 - 0.19 %

Description: It is dwarf 'growing shrub, hardy and leaves are big having wavy margins. Flowers may be single, semi double or perfectly double

Glossary of some medical terms:

1	Abortifacient	:	An agent that promotes abortion
2	Alterative	:	A drug, which corrects disordered process of nutrition and restores the normal function of an organ or of the system
3	Anodyne	:	A drug, that relieves pain
4	Anthelminthic	:	A drug, that kills intestinal worms
5	Antipyretic	:	A drug, which reduce fever

6	Antispasmodic	:	A drug, which counteracts spasmodic disorders
7	Aphrodisiac	:	A drug, which promotes sexual desires
8	Carminative	:	A drug, which relives flatulence
9	Demulcent	:	An agent, having a Smoothing effect on the skin and mucous membranes
10	Diuretic	:	A drug, which increase the secretion an discharge of urine
11	Emetic	:	A drug, which induces vomiting
12	Expectorant	:	A drug, that promotes the removal of catarrhal matter and phlegum from the bronchial tubes
13	Febrifuge	:	An agent, used for reducing fever
14	Refrigerant	:	A drug, which relieves feverishness for produces a feeling of coolness
15	Sedative	:	A drug, which reduce excitement irritation and pain
16	Vermifuge	:	A drug, which expels intestinal worms

Student Activities:

1) Collect the samples of medicinal and aromatic plants present in our campus.

2) Classify medicinal and aromatic plants on the basis of family, use and method of propagation.

3) List out some names of Ayurvedic medicines with their ingredients available in the market.

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EXERCISE – 4
GARDEN ADORNMENTS & FEATURES

OBJECTIVE: Study of different garden adornments and garden features.

GARDEN ADORNMENTS

1. **Garden-seats**: The garden-seats should not look out of place. They should be comfortable, durable and artistic looking. Seats made out of wooden or fabric material are comfortable to sit compared to those built in stone or iron. The wood used is to be treated with a preservative and painted with moisture proof chemicals. Iron or stone or concrete seats get easily heated in the summer months and become cool in the winter months, thus making them uncomfortable to sit. Concrete or stone seats are preferable in public parks as they are durable in nature.

2. **Ornamental tubs, urns and vases**: The tub or the vase can be made of timber or preferably of brick, concrete or carved out of stone, which can be kept permanently or temporarily. These can be positioned over ornamental pillars, at the end of paved paths, near the gate or near the staircase of the main entrance. Ornamental urns made of metal with carvings outside look beautiful in the terrace, near the staircase or even inside the house.

3. **Bird bath**: It is a large, bowl-shaped container generally made of concrete, fixed over a pillar or column, which is about 1m tall. Water is stored in the bowl for the birds to come and drink or bath in it. Bird baths may be constructed at the quiet corner of the garden.

4. **Sun dials**: It can be used as a focal point in a garden, can form a centerpiece of a formal flower bed, and can be placed in the centre or at the end of the lawn or at the junction or termination of path. It is also a good feature in a sunken-garden. The sundial should be positioned in a place where the shadow from a tree or building does not fall for a long duration.

5. **Floral clocks**: These are huge clocks generally operated by electricity, having huge hands for showing the seconds, minutes and hours. The machinery of the clock is concealed in an underground chamber with only the hands showing above the ground against a dial of carpet bedding plants or flowerbeds. Instead of live plants, the dial can be decorated with various coloured pebbles.

6. **Other garden adornments are:** Japanese lanterns, Ornamental stones, Fountains, Statues, Plant stands, etc.

FEATURES OF GARDEN

(1) Garden Walls:-

- In a garden, for safety or to cover the ugly sight, it is necessary to construct a wall of brick, concrete or stone along the periphery of the garden.
- Low brick wall of 2-3 feet & some grill over it will not obstruct complete view.
- To break drabness of concrete one may grow creepers such *ficus repens* over the wall.

(2) Fencing:-

- Fences are needed for marking the boundary and for protection.
- It is also used to separate one part of garden from other parts.
- Wood, bamboo, wire, wire netting, chain link fencing is used for this purpose.

(3) Steps:-
- Steps are necessary when path goes from one level to another level of the garden.
- Concrete, stone, wood, or gravel used for making the steps.
- Narrow & steep steps are unsuitable as they cause discomfort in climbing.

(4) Drives and Paths:-
- It provides a flat, dry and pleasant passage for the person or vehicle & it should be harmonize with other garden feature.
- Path with graceful & gentle curve looks much better than straight path.
- Drives are made up of gravel, asphalt, concrete.
- Paths are made up of gravel, paving stones, crazy paving, bricks, grass.

(5) Hedge:-
- Shrubs or trees planted at regular interval to form a continuous screen are called a hedge.
- It serves the purpose of fencing ensure privacy, screen ugly and unwanted spots (manure pits, lavatory, servants quarters etc.), create background for a floral display, separate different parts of garden.

(6) Edge:-
- Edge plant should grow very low as its purpose is to provide lining, decoration and demarcation only. There are two types of edge- Non living edge (bricks, tiles, stones, concrete) and Living edge (grass, shrubs, annuals & other)

(7) Arches:-
- A garden may need arches for training climbers are generally constructed near the gate or over the paths in a garden. An arch should be at least 2 to 2.5 m high.

(8) Pergola:-
- Series of arches is known as pergola.
- It is constructed over pathways and climbers are trained over it.
- It is used as a resting place during the summer.

(9) Terraces:-
- In hilly area it is not possible to have large piece of land in one plane for laying a garden.
- So garden is laid in terraces.
- But in plains terraces break monotony and bring novelty in the garden.

(10) Lawn:-
- Lawn is a green carpet of landscape. It is also known as heart of the garden.

(11) Carpet bedding:-
- It means covering area with dense low growing herbaceous plants.
- It looks nice when grown on slope or slanting area.
- It is possible to set some design, figure or letter with different plant material.

(12) Flower beds:-
- It is used to display flower in a best possible way.
- It can be of any size & shape.
- It is a main feature of formal garden & almost in a Geometrical design.

(13) Shrubbery:-
- Group of shrubs planted together is known as shrubbery.
- It is used for hiding one portion of the garden from the other besides adding beauty.

(14) Borders:-

- Beds which are more in length than breadth are known as borders.
- There are 3 types border
    1. Herbaceous border
    2. Annual mixed border
    3. Mixed border

(15) Rockery:-

- Rockery is a permanent feature of a garden.
- Rocks are arranged carefully, to make a mound or any desired shape and plants are planted between the spaces of rocks.
- Generally bushy and hardy flowering plants, succulents and low water requirement plants are planted.
- Cascade (water fall) can be prepared in a rockery.

Student Activities:

1) List out important garden adornments and features present in our campus with their location.

2) Draw the diagrams of important garden adornments and features.

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EXERCISE – 5
TRAINING AND PRUNING OF ORNAMENTAL PLANTS

OBJECTIVE: Study of principles, method & need of training & pruning in ornamental crops.

Training and pruning are important operations. Both the operations form an indispensable process having direct bearing on growth and vigour of plants and yield and quality of flowers / fruits. A properly trained and pruned plant sustain heavy crop load and produce bounteous harvest of quality. Both the operations of training and pruning work together in maintaining shape and size of tree and harvesting desirable yield.

1. **Training:** Training refers to the judicious removal of plant part / parts to develop proper shape of a plant capable of bearing a heavy crop load.

Training is a treatment given to the young plants to get a suitable or desirable shape with strong framework. It may or may not involve pruning.

The reasons / objectives for training ornamental trees, shrubs etc. are:

- There are no. of plants, which grow wild and don‘t bear if they are left to themselves and will not have any symmetry in their growth.
- Most of the time, the untrained trees put forth vegetative growth only. Hence, bearing will be delayed.
- When plants are grown in rows at close spacing, they grow tall and occupy interspaces, making intercultural operations difficult to practice.
- For want of sunlight, the lower branches wither and die. The shaded flowers/ foliage fail to develop colour.
- Untrained trees will generally be less productive because of excessive vegetative growth for most of the time.
- The framework being weak in untrained trees, it breaks easily due to strong winds as well as heavy loads of crop. All the above problems can be overcome by training the trees.
- Man can train the plant to suit his desire.
- The flowering and ornamental shrubs etc. can be trained to a particular shape like animals, birds etc.

Principles of training:

1. Formation of the mainframe work must be strong the branches must be suitable spaced apart and the tree must be balanced on all the sides.
2. Never allow several branches to grow at one place or very near each other.
3. Careful training of main branches is very essential.
4. Another important point about training is that if two branches are growing at the same point try to train them to grow at a wider angle. Narrow angle is always weak.

2. **Pruning:** Pruning is refers to removal of parts of a tree, especially shoots, roots, buds, or nipping away of the terminal parts.

Objectives:

- To remove the unproductive growth, because plant bears flowers on a new shoot.
- To ensure production of large number of strong and healthy shoots.
- To improve the flower production with quality.
- Pruning will force the eye bud to produce the strongest shoot.
- It keeps the plants in proper shape and size.
- To allow light and air to reach the centre of the plant.
- To facilitate various cultural operations like hoeing, weeding, soil scraping, sterilization, manuring, harvesting etc.
- To rejuvenate the old plants. Cut off the old plants from the base to get strong shoots.
- To remove dried and diseased affected portion of the plant.
- To make a plant more manageable for maximum returns.
- To give more aesthetic look to plant.

Pruning in Rose:

- Pruning is done once in year during second or third week of October.
- In old hybrid tea bushes, the previous season's thick shoots are pruned up to half the length, keeping about 5 or 6 eyes on each stem.
- In Hybrid tea and Floribunda, keeping only 3 or 4 shoots with 3 or 4 eyes from the base to obtain exhibition blooms.
- A slant cut is made little above an eye.
- Floribundas are pruned moderately.
- The climbing roses do not require any pruning, except the removal of unhealthy and dead twigs.

Where and How to Prune Roses:

- Every rose stems has eyes (buds) alternating on opposite sides in the leaf axils (usually outward and inward).
- The basic rule in pruning is always to make the cut about half a centimeter above a vigorous bud that finds in the direction one desires the new shoot to grow.
- Since the rose bush has to be kept open in the centre.
- The cut is made at an outward growing bud in standard roses as well as in floribundas.
- Where as in climbing roses the pruning is done at a bud pointing more or less upward.
- Always encourage outward bud to expose the center open.
- Whichever the bud is selected the cut should be slightly slant. As the horizontal cut retains moisture / sap and therefore, is liable to cause fungal growth,
- While making the cut care should be taken not to make it too high above the eye (bud) as there may be chance of die back of shoot.
- On the other hand if the cut is very nearer to the bud, it may die due to want of sap flow. So cut one inch above the bud.
- It is absolutely necessary to cut the sharp end clean because the broken tissues, bruises or hanging shreds of bark will invite for infestation of pests & diseases.
- All the cut ends should be pasted with cane sealer (copper fungicide) against the attack of fungus and cane boring insects.

- Within a fortnight after pruning new flush of growth will start and within 45 days of pruning new flowers are ready for harvesting.

Types of pruning:

The intensity of pruning markedly influences the growth and flowering or roses depending upon the extent and level of shortening, there are three types of pruning.

1. Light pruning – strong & sturdy plants are prunes lightly.
2. Moderate pruning – moderate growers pruned moderately.
3. Hard pruning – weak plants/old bushes.

Student Activities:

1. Differentiate between training and pruning with examples.

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EXERCISE – 6
TRAINING AND PRUNING OF ORNAMENTAL PLANTS

Planning and layout of garden is as important as planning of a building. It is a useful exercise to draw the plan on a paper with proposes and position of the garden features, according to size, shape, colour and structure. The art of designing of garden is known as landscape gardening. Planning and designing known as Landscape architecture of Landscape gardening.

I. Styles of Garden:

1. Formal Garden:

It is laid out as per symmetrical or geometrical methods, In such gardens everything is planted in straight line or curve. The plants, flowers beds, borders, shrubbery are arrange in geometrical design. e.g. Mugal, Persian, Italian and Frech garden.

Features of a Formal Gardens:

- First plan is made on paper and then land is selected accordingly.
- Land is leveled.
- Symmetrical design.
- Geometrical: Square, rectangular, circular beds and borders.
- Roads and paths cut at right angle.
- Balance is symmetrical as same feature replicated on both sides of central axis.
- Hedges, edges and topiary are trimmed.
- Trees can be selected as individual feature.

2. Informal Garden:

The whole design looks informal as the plants and the features are arranged in natural way without observing hard and fast rules but planning is done with the think of fully, maintain, creation and attraction. The idea behind this design is to initiate the nature. e.g. English and Japanese garden.

Features of a Informal Gardens:

- Plan is forced to fit the land
- Main aim is to capture natural scenery
- Land is not leveled
- Asymmetrical design
- Non-geometrical beds and borders
- Untrimmed hedges, edges and topiary
- Individual plants are not selected as feature

3. Wild garden:

The term "Wild garden" was given by William Robinson in the last decade of 19 the century. The concept of wild garden is not only against all formalism but is also breaks the rules of styles. The grass remains unmoved and bulbous plants are planted scatter.

II. Creating a new garden:

It is important to design the garden in relation to its setting and to take into account some factors such as soil type, slope, weather, local planting materials, irrigation facilities, etc. It may seem simple to dig up the entire garden which has jungle-like tangles of trees and neglected shrubs and weeds. But it is better to proceed with caution. The inclusion of one or more mature specimens in a new garden provides a framework around which to design the planting scheme and also helps to counteract raw appearance.

III. Considerations for garden designing:

The basic considerations to be taken before developing a garden are given below:

1. **Climate:** This includes annual rainfall, relative humidity, temperatures, sunshine hours and special climatic influences on particular area. For example, town gardens are usually warmer and more sheltered all year round than those in rural areas. In addition, the microclimate should be assessed such as which parts receive sun and shade in different time of the day and of the year.

2. **Soil:** It is essential to find out characteristics of the soil which includes, type-heavy or light, texture-clay or sandy, acidic or alkaline (pH), etc. The soil types affect drainage, the type of plants that may be grown, type of irrigation and the ease of cultivation tasks such as digging and planting.

3. **Design:** When designing a garden, consider it in the context of its surrounding rather than in isolation. For example, it may be in a terrace or suburban setting with good or bad outlooks. The more detailed plan may be drawn showing view of site, direction of wind and where shelter or screening is required.

4. **Maintenance:** All gardens need some care and attention to keep them in good conditions. Before deciding a design, be realistic about the amount of work and energy required for maintenance of the garden. Also assess how much time and help will be available or affordable for different operations.

5. **Cost:** This includes all type of cost like cost of construction, cost of soil preparation and modulation, cost of irrigation system, cost of establishment of plants and their maintenance cost. During planning and designing one has to consider the expenditure of the garden as well as the budget of the owner and then planning should be carried out.

IV. Steps for crea tion of design:

1) **Exploiting natural characteristics:** Always try to work with given conditions using natural features of site. Slopes, banks and changes in level may offer scope for constructing terraces, retaining walls, stepped beds, a watercourse or a rock garden. Poorly drained or damp problem areas are good for making bog or marsh gardens using moisture loving plants.

2) **Assessing existing features:** Make separate lists of planting material and hard elements present on the site. Note their position in the garden. When preparing garden plan, this information will be helpful to decide which element or plant to reposition or remove or modify.

3) **Measuring the site:** First of all, measure the boundaries of the plot. If the site is irregularly shaped, divide it into small sections and measure it separately. Alternatively, a surveyor may be employed to prepare a scale plan.
4) **Making a scale plan:** Next step is one has to draw a scale diagram of the site as a basic plan on which various designs may be drawn. These may differ greatly in styles; the space allocated for each feature, and the sense of proportion, but makes each one on a scale plan so that it has a realistic basis.

5) **Changes of level:** If there are marked changes of level on the site, indicate this at the survey stage, as the new design may have to incorporate certain features to accommodate the gradients. A gentle slope may keep as such for proper drainage and a steep slope may necessitate the building of terraces or retaining walls.

6) **Preparing the first plan:** The site measurements take on paper to create a scale-based plan of the garden which should include all boundaries together with all elements which one want to retain from the existing garden. If making several different designs for comparison, draw each on tracing paper fixed over this scale plan so there is no need of redrawing.

7) **Choosing the design style:** There are many variations of styles that provide potential for creating a unique design but preference is given to personal taste. All the basic principles should be kept in mind, whatever may be the design. Style of the garden is also depending on position and surroundings of site.

8) **Drawing up the final design plan:** Draw this working plan accurately as per the scale on paper, using numbers and symbols for various features. Also indicate the proportion and size of the feature so they may not create problems on ground.

9) **Planning the work:** Designer has to prepare a schedule, before embarking on construction and cultivation, to minimize disruption on the site so that the messiest and most elaborate operations, such as constructing a patio or wall, are carried out first. Planting process require clear site, proper time and season for survival and establishment.

10) **Planting:** After completion of skeleton of garden means marking and development of hard elements like paths, steps, walls, etc. Planting should be carried out carefully. Growth rate and size of plant after due course of time and at maturity should be kept in mind. Old hedge or shrubs of poor condition should be removed and replanting with new should be done.

V. Planning or designing is done on the basis of following points.

1. Planning is done according to the hobby and judgment of the owner.
2. As per climate, soil and topography of the land.
3. The position and design of the building or locality.
4. The size of house or building
5. Source of water, availability of labour and cost.
6. Do not copy down other garden, one has to develop own design.
7. Avoid overcrowding of plants position.
8. Maintain colour, harmony, balance fragrance.
9. Provide attractive frame work.
10. Large compound divided in sub plot.
11. Shape the tree and shrub may take into consideration.
12. Prefer a fountain with a statue.
13. Use wind barriers on back side of the house.

VI. Procedure of layout of garden:

1. Observe the site carefully.
2. Remove big stone, stubbles, unwanted foliage, creepers, trees, etc.
3. Cultivate the land, leveled area as far as possible but make slope, elevation as per architecture looks.
4. Measure the area.
5. Demarked the land and make sub plot.
6. Designed the road and path according to the site and requirement.
7. Fix the focal point or statue as on attraction place.
8. Make live boundary line (hedge) and divisional line (edge) as per requirement.
9. Draw geometrical design for flower bed near the road side and boundary line on free hand based.
10. Planting of decorative foliage plant on division line.
11. Make mass effect with shrub, creeper, flowering plants *etc*.
12. Raised the lawn.
13. Designed the rockery if require.

Student Activities:

1. Draw or prepare a layout of formal and Informal garden styles.
2. Give examples of different types of Mughal gardens in India.
3. Give examples of different types of Japanese gardens in India.
4. List out different features of Mughal, Japanese & English gardens.

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EXERCISE – 7
SPECIAL PRACTICES AND INTERCULTURAL OPERATIONS IN ORNAMENTAL PLANTS AND MAP

I. Special Practices in Ornamental Plants:

1. **Bending:** Bending is a major operation necessary to get good quality cut flowers especially done in Roses. It also helps in buildup of strong framework along with good quality flower stem development. Just as the plant is 1-1.5 months, first bending can be carried out. Three–four stems arising after pinching, these should be allowed to develop dark green in colour (stem bronze or reddish leaves should not be selected for bending) and then the weaker ones should be bended. Just one or two stems strong enough should be allowed to grow to bear the flowers.

   Bending procedure:
   - Bending should be carried out carefully.
   - Bud should be pinched off from the branched intended to bend.
   - The branch which arises from the main shoot of the plant, leaving two healthy leaves, the portion above is pressed hard with a twist to split the inner stem portion, than again pressed with thumb and bent smoothly towards the path side of the bed with thumb and index finger.
   - Care should be taken that the stem does not break.
   - The bend should be more than 90°.
   - If the branch is likely to break with a strong bend than two close bends can be given so that the end stem part is bended at more than 90°.
   - The two-leaf axil buds later produces strong healthy tall shoots with flowers.
   - This process is repeated.
   - By this process stronger shoots are selected and weak ones left as pinched stems to provide leaf cover.

   Principle:
   - The main idea of bending is to encourage the plant for healthy framework at bottom which will give strong-lengthy stalks.
   - The bended stem however weak, contribute in increasing carbon assimilation via enhanced photosynthesis with better surface leaf area exposed to light.
   - Vegetative growth also gets impetus via bending which forms the basis for development of shoots.
   - By bending treatment, the dormant buds below the bend get extraordinary impetus, through reduction of apical dominance and thereby produce long and strong shoots with flowers.

2. **Pinching:** Pinching is refers to the removal of the growing tips of the plant to induce the growth of vegetative laterals. Chrysanthemum, carnation and marigold required pinching.

   - Objective: Encourage the branching to produce a bushy growth or production of flower buds.
   - Time of pinching: At the young stage of the plant.
   - Procedure: With the help of thumb and forefinger the top portion of the plant should be removed, although knives and scissors can also be used.

3. **Disbudding:** Disbudding is important for development of the main bud as it consists of removal of all the axillary buds just below the main bud at early stage is known as disbudding. Eg. Rose, chrysanthemum and annual and perennial plants required disbudding.

   Disbudding in Chrysanthemum:
   - ➢ This operation is done for large-flowered and decorative chrysanthemum.
   - ➢ For taking 3 blooms/plant, the first pinching is done in August.
   - ➢ Three lateral strong shoots are allowed to grow and others are removed.
   - ➢ Disbudding should be start in October.
   - ➢ Lateral buds and side shoots are removed at early stage of growth from time to time.
   - ➢ For taking one bloom/plant no pinching is done.

4. **De-shooting:** Removal of unwanted or water shoots. Perennial plants produce numerous side shoot which do not bear the flower or inferior quality flower. Only specific shoot are allowed and others are removed at early stage Eg. Carnation & chrysanthemum for exhibition.

5. **Defoliation:** Removal of foliage (leaves) is known as defoliation.
   ¾ Objective: For inducing flowering or to reduce transpiration.
   ¾ Procedure: Removal of leaves by hand or by secateurs with holding water. Eg. Jasmine.

6. **De-suckering:** It is nothing but the removal of suckers. As the plant grows, a number of suckers also grow from the base of plant or rhizome. These suckers compete with the main plant for its food and nutrients. Thus, controlling these suckers is a must to maintain normal bunch weight and quality. Eg. Gerbera, chrysanthemum, etc.

7. **Thinning:** Removal of the undesirable growth like inward growth, weak stems, blind shoots, crowded growth.

8. **Bud Capping or Topping:** The developing buds as they appear reaching maturity in 2-3 days are covered with bud nets made up of nylon nets. The bud net maintains the bud in proper shape, maintains it compactness and also helps in proper development with some effect on modified atmosphere surrounding the bud. Eg. Rose.

9. **Wintering:** It is the treatment of exposing the roots to sun light around the plant especially done in roses by digging the soil up to certain depth which will increase & improve flower yield and quality.

10. **Netting (Trellising):** It is done in carnation as it is a very fragile and herbaceous plant and growing stems tend to fall on the sides under their own weight. Hence, plant support by netting is very important. Staking with 4-5 layers of galvanized metal wire or of nylon rope fixed to the frames is an important practice. The first net of the size 7.5 x 7.5 cm mesh (squares), is tied 10 cm above the ground surface and the subsequent nets of 15 x 15 cm mesh are tied at every 15 cm to 20 cm distance from one another. The total 4-6 number of net layers is required to be, tightly stretched on supports. The nets are usually laid before planting. Rooted cutting are planted within the netting and successively raised with plant growth.

11. **Topiary:** It is an art of clipping & trimming shrubs or trees into different ornamental shapes i.e., of birds, animals, domes, umbrellas, etc. It is an old art but now-a-days it is becoming popular in city parks to recreate visitors specially children's.

Characteristics of plants:

- Plant should be quick growing in nature.
- Leaves should be small, green or yellow in color.
- Ability to withstand frequent clipping/pruning practices.
- Produces good number of lateral shoots.
- Eg. *Duranta plumari*, *D. variegata D. goldiana*, *Thuja orientalis*, etc.

12. **Staking:** Staking is necessary to keep plants erect and to maintain proper shape of plants and bloom. Stakes are prepared mostly from bamboo sticks. It is required for vertical support of the plants.

13. **Use of growth substances:** To some extent some growth regulators like GA_3 and retardants like CCC are used to get more number of flowers with good quality. GA_3 @ 100 to 300 ppm has been found to increase the stalk length, flower size and reduce number of blind shoots in different flower crops.

14. **Mulching:** It is another important cultural operation to maintain optimum soil temperature, conserve soil moisture, suppress weed growth and produce more flowers of better quality. Flower crops beds can be mulched with straw, dry grasses, black polythene film, etc.

15. **Soil sterilization:** Before plantation of, soil disinfection is absolutely necessary. In particular, the fungus is a menace to several crops. The various methods of sterilization are;

   a. **Steam**: Not economically feasible for Indian conditions.

   b. **Sun**: Cover the soil with plastic for 6-8 weeks. Sunrays will heat up the soil, which will kill most fungi.

   c. **Chemical sterilization**:

   - Use of formalin @ 7.5-10 lit/100sqm. This pure chemical should be diluted 10 times in water and then sprayed / drenched on beds.
   - Cover the beds with plastic sheets for 7 days.
   - Then flush the soil approximately with 100 liters of water per sq. m to drain the traces.
   - It is advised to wait for 2 weeks before plantation.
   - Other chemicals that can be used are: Methyl Bromide @ 2530 g/sq.m and Basamid (Dazomet) @ 30-40 g/sq.m.

II. Special Practices in Medicinal & Aromatic Plants:

1. **Drying:** It is carried to minimize the moisture from the plant or its product in order to increase its storage life.

   Methods of drying: Natural drying under sun, Solar drying, Oven drying, Freeze drying, Dehydration, etc.

2. **Curing:** Some bulbous plants are cured for at least two to three weeks or until the tops necks of stem are completely dry and the outer skin becomes slightly crispy on the field itself after harvesting.

3. **Earthing up:** Earthing up hilling or ridging is the technique in of piling soil up around the base of a plant. It can be done by hand (usually using a hoe) or with powered machinery, typically a tractor attachment. It buries the normally above-ground part of the plant, promoting desired growth. It also encourage the rooting and is be used to stabilize the stems of crops which are easily disturbed by wind.

4. **Gum Tapping:** It is generally done in guggal for obtaining gum. The plants are ready for gum tapping after 4 to 5 years of planting. Minimum thickness of stem should be 5 cm.

   Method of tapping: Bark deep (that is shallow) incision is to be made on bark and while carrying out the incision a small quantity of guggal gum (mixed with water) should be applied to the incised place using the prick–chirel for incision. For this purpose, the sharp end of the instrument is dipped in the guggal solution and an incision is made on the bark, taking precaution that a small amount of guggal solution present on the prick –chirel reached inside the incised bark.

   Time of incision: In March-April in Gujarat condition.

5. **Rejuvenation:** Some plants or trees after attaining certain age do not or produce very less flowers, so at that time the rejuvenation is practiced to overcome this problem.

   Rejuvenation in Scented Rose:
   - Yearly observations have shown that rose plantations do not have a uniform rate of production.
   - In the first 5 to 6 years the flower yield rises, but after the sixth year the flower production declines and after 8-10 years, the roses become unprofitable, necessitating rejuvenation.
   - Autumn is the most favourable time for rejuvenation.
   - The bushes are cut down to the base and on both sides of the rows, trenches 18-20 cm deep are opened and the soil is spread in the inter-row space.
   - In these rows, 20-30 t of FYM along with 60 kg/ha each of P_2O_5 and KO_2 are placed and covered with soil.
   - In the spring, new shoots develop and out of them only six to eight vigorous branches are allowed to grow.
   - After 2 years, the yields of rose flowers reach the previous level and the life of plantation is increased by a further 8-10 years.

<u>III. Intercultural Operations in Ornamental Plants and MAP:</u>

1. **Hoeing:** Light hoeing is a very effective way to keep soil porous so that light, air and water may reach the roots better to improve moisture capacity and to keep the beds free from weeds. Eg. Roses are shallow rooted plants and roots of establishment plants tend to grow near the surface. Hence, shallow hoeing is preferred, as deep cultivation destroyed the rootlets.

2. **Weeding:** Control of weeds in fields is one of the most expensive operations in commercial cultivation. Hand weeding is normally take recourse to keep the plants free from weed competition. The use of herbicides appears to be economical, convenient and efficient in controlling weeds in the field but having environmental hazards.

Student Activities:

1. Draw the figure of bending, pinching & disbudding.
2. Give 5 examples of crop requiring pinching and disbudding.
3. Discuss the types of pinching.

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EXERCISE – 8
HARVESTING AND POST HARVEST HANDLING OF CUT AND LOOSE FLOWERS

Post harvest care is one of the most important factors influencing the quality of flower, a highly perishable commodity. It rather decides the face value of the flower at national and international market. The cut flowers are highly perishable in nature and an enormous loss up to 50% of the farm value may occur during the entire market chain in view of lack of improper post harvest care. It is the post harvest technology that has the potential to rescue the post harvest losses and further to maintain improved cut flower quality and vase life.

HARVESTING OF CUT FLOWERS:

Harvesting of cut flowers should be done in proper way, considering the following points:

a. Stage of harvest:

Harvest stage is dependent upon market distance. Flowers may be selected at some advanced stage while for distant markets especially for export; flowers at early stage should be selected.

b. Time of harvest:

Early morning or evening time should be preferred for harvesting of cut flowers.

c. Mode of harvest:

Flowers should be harvested using sharp tools to obtain sharp and slant cut.

Stage of harvest:

Flowers should be harvested at a proper stage for a prolonged life. Harvesting stage is also influenced by the distance to the market. For local markets flowers can be harvested at advanced stage also.

Optimum harvesting stage for some important flowers is given below:

SN	Flowers	Harvesting stage
1	Roses	Tight bud but developed stage.
2	Gerbera	Ray florets are fully expanded; two whorls of disc floret become mature i.e open and perpendicular to the stalk.
3	Chrysanthemum	Standard: Fully open before the central disc is fully mature. Spray: When four flowers are fully open before the pollens are shedded. Decorative:Centre of the oldest flower fully open.
4	Carnation	Fully developed bud at paint brush stage.
5	Orchids	Most species: Fully open flowers. *Dendrobium*: 75% inflorescence is open.
6	Anthurium	When one third to one half of the spadix shows change in colour (mature).
7	Gladiolus	Basal two buds show the colour.
	Tuberose	Single: Buds are fully developed but yet not open. Double: Basal 3-4 buds start to open.

POST HARVEST TECHNOLOGY IN CUT FLOWERS:

It is important to know the factors, which influence the postharvest quality of cut flowers in order to develop post harvest handling strategy. The various factors, which should be considered for postharvest handling technology in cut flowers:

1. Flower sensitivity to ethylene:

Ethylene is an important factor influencing postharvest quality and life of flowers. There is production of ethylene in cut flowers and a peak in ethylene is observed just before flower senescence.

Flowers show variation in their behaviour towards sensitivity to ethylene i.e. few flowers are highly sensitive while some are less sensitive to ethylene. Flowers like rose, carnation, chrysanthemum etc are highly ethylene sensitive while flowers like gladiolus, tuberose, etc are low to insensitive to ethylene. There is need to treat ethylene sensitive flowers with anti-ethylene compounds to improve their longevity and quality.

2. Consumer Preference:

Consumer preference is generally observed in stalk length, bud size and at the stage of bud opening.

3. Distance to the market:

The stage of harvest is dependent upon distance to the market. For long distance, firstly, the flowers should be harvested at early bud stage and secondly, proper packaging is must to ensure quality at the distal end. Further, pulsing treatment should also be employed. However, for short distance markets i.e for direct sale, one can go for some advance stage of harvesting.

4. Market – status/Position (High or low):

Generation of market information and accordingly formulation of market strategy is necessary. Here, post harvest technology plays a vital role. It is very important to know the prevailing market status for the particular flower. The factors influencing status flower market like festival time and should well be identified in advance. Accordingly, the post harvest technique of packaging and storage can be identified.

POSTHARVEST TECHNIQUES:

1. Conditioning:

Conditioning or hardening is a simple process of restoring flower turgidity. Flowers are treated with de-mineralised water supplemented with germicides and acidified with citric acid to pH 4.0 to 5.0. Some chemicals like STS, 8-HQC, 8-HQS, sucrose, etc can also be used for conditioning. Wetting agent like Tween-20 @ 0.01-0.1 per cent can also be added. More wilted flowers can be immersed in water for an hour and then transferred to plastic container with the stems in warm water and placed in cold room.

2. Pre-cooling:

Flowers harvested should be immediately placed in distilled water after rehydration and then should be moved to cold storage without packaging for pre-cooling till a desired temperature is reached. Pre-cooling is fast removal of field heat and it is important to slow down the metabolic activities of cut flowers. Pre-cooling temperature varies with the species and cultivars: Alstroemeria 4° C, Anthurium 13° C, Dendrobium 5-7° C, Carnation 1° C, Gladiolus 4° C, Rose 1-3° C, Chrysanthemum and Cymbidium (0.5-4° C). Pre-cooling reduces respiration rate and decreases breakdown of nutritional and other stored material in the stems, leaves and petals, delays bud opening and flower senescence. It also delays rapid water loss and decreases flower sensitivity to ethylene. Several pre-cooling techniques such as room cooling, forced air cooling, hydrocooling, vaccum cooling and ice bar cooling are available.

3. Impregnation:

It refers to permeation or infusing of the stem ends for a short time with chemicals. It protects the blockage of the water vessel in stem by microbial growth and decay. Chemicals like CoCl2 or $NiCl_2$ are used at high concentration for a period of 10-15 minutes. Flowers like aster, gerbera, carnation, chrysanthemum and Phalaenopsis respond to it very well.

4. Pulsing:

Pulsing is a short duration treatment given to cut flowers in form of high concentration of sucrose. It is a principle, in which plant tissues are filled with carbohydrates to ensure sufficient substrate for the flowers to mature and possess longevity. Fresh cut flowers are pulsed by placing lower portion of flower stems in solutions containing sugar and germicides for a period ranging from few hours to 2 days, depending upon the flower species. The addition of sucrose in the vase water alone, may encourage increased growth of micro-organisms in the vase medium. Hence, the antimicrobial agents e.g. 8-HQ, 8-HQS, 8-HQC, silver salts, citric acid, etc should also be incorporated to enhance better solution uptake that would suffice maximum effects of the supplied sugar. The concentration of pulse solution varies in different flowers. Generally for rose and carnation, 5-8% sucrose solution is sufficient while for multi-floret spikes like gladiolus and tuberose, high concentration of 10-20 % is needed.

5. Preservative –Solution:

Preservative or vase solution refers to a solution consisting of sucrose, anti-microbial agent and or growth regulator in which cut flowers can be continuously placed. Basically, the concentration is much lower than pulse solution. The anti-microbial agents like 8-HQC, 8-HQC, Aluminium sulphate, anti-ethylene agents like STS, $AgNO_3$, and acidifying agents like Citric acid are widely used as vase solution. Even plant growth regulators like gibberellic acid, Benzyl Adenine, are also reported to improve vase life and quality of gladiolus and chrysanthemum. Growth retardants like CCC, SADH and MH have also been reported to improve vase life of some cut flowers. Ethylene inhibitors like Amino ethoxy vinyl glycine (AVG), Methoxy vinyl glycine (MVG) and Amino oxyacetic acid (AOA) are beneficial in ethylene sensitive flowers.

6. Grading:

Grading means grouping of flowers based on quality prior to marketing. Grading is done on the basis of appearance, stage of maturity, blemishes or injuries due to diseases, insect infestation, colour, size of the bud, straightness and stem length. All the requirements for quality should be fulfilled in a particular grade for export. Flowers should look fresh, turgid and spot-less along with proper bud size and stalk length as per the requirement. In US, the society of American florists has recommended four types of grading of cut flowers such as blue (fancy), red (special), green (Std), and yellow (Utility). Grading is done manually scale fixed on stand on a platform. Recently, new techniques like machine vision system, image processing techniques, neutral network analysis, Bayes decision theory etc are being developed for flower grading.

7. Packaging:

Packaging plays a major role in flower quality, appearance and opening ability. Poor packaging practices lead to deterioration of the quality and poor market value. The cell turgor controls the structure of plant organ, while the loss of water due to improper packaging induces a stress, which in turn hastens the senescence and reduces the vase life. Proper packaging of the cut flowers is must for ensuring good quality at the retailer or customer end even after long transportation or storage duration.

Merit of packaging:

- It protects flowers from bruising and physical injury during transportation.
- It brings down rate of metabolism
- Maintains turgidity in cut flowers and avoids dehydration effect of cold storage
- Minimizes low temperature chilling injury during cold storage
- Improves opening ability in cut flowers
- Retains petal pigments
- Maintains overall freshness and quality

Types of Packaging : The packaging of the cut flower is basically of two types:

i. Internal packaging

The internal packaging consists of direct packaging of the cut flowers with a single or double layer film.

Types of packaging films

The different types of packaging films have different air permeability rates. Hence, depending upon the requirement, the flower type, temperature and duration, the packaging film should be selected.

- ❖ Cellophane
- ❖ Polypropylene
- ❖ Low Density Polyethylene
- ❖ High Density Polyethylene
- ❖ Polypropylene
- ❖ Paper: Butter paper, parchment paper and Newspaper
- ❖ Corrugated paper (wrapping in rose)

ii. External Packaging

External packaging is done for protecting the cut flower from physical injuries or bruises during the transport system. The Corrugated Fiber Board (CFB) boxes of different sizes with or without vents are found to be highly beneficial for the external packaging of the cut flowers. The CFB boxes posses good physical strength depending upon the number of layers used in the CFB sheet. The box should be strong enough to support the weight of at least 8 full boxes placed on the top under high humidity. The minimum length of the boxes should be about twice the width and its width about twice the height. The boxes are tested at 0°C and 100 per cent RH for drop test, compression test and vibration test. Total vent should be equal to 4.5 per cent of the area of the end walls and should be avoided near the corners. Some of the dimensions of the box is as given below. Shredded papers or paper pillows can also be placed inside the box to avoid bruising injury to the flowers.

Box dimension:

SN	Flower	Length (cm)	Width (cm)	Height (cm)	Weight (kg)
1	Rose	100	40	30	17
2	Carnation	100	40	20	13
3	Chrysanthemum	80	50	23	15
4	Gladiolus	120	50	15	15

8. Storage:

Storage of flowers at optimum stage and quality is important for high market value. Flowers can be stored generally in two ways, dry storage and wet storage. For long term storage dry storage is beneficial as it restores the flowers stage while for short term storage wet storage can be employed. Dry storage consists of packaging and cold storage of flowers while wet storage employs placement of flower stems in preservative solutions for required duration in cold storage. Basically, there are three types of storage system as given below:

a. CA Storage
b. MA Storage
c. Hypobaric Storage

a. CA storage:

Controlled atmosphere (CA) refers to intentional alteration of the natural gaseous environment and maintenance of that atmosphere at a specified condition throughout the distribution cycle, regardless of environmental variations. It is normally applied for long term distribution and long term storage especially in fruits rather the flowers. Controlled atmosphere storage consists of advanced storage system in which component gases are precisely adjusted to specific concentrations and maintained throughout the storage with highly controlled temperature. The desired mixture of gases like 2-5% oxygen and 3-10% CO_2 and 80-90% Nitrogen is maintained throughout the storage duration. The CA storage of produce has been reported to reduce respiration, inhibits ethylene production and action and retards ripening and improves quality of fresh produce. Number of systems is available for CA Storage as given below:

- External Gas Generator: For replacing of O_2 with CO_2.
- Liquid Nitrogen Atmosphere generators: Flushing with sprayed liquid nitrogen.
- Gas separator systems: CO_2 and O_2 are selectively removed from the storage and N_2 continues into the storage space.
- Carbon dioxide Control systems: Based on scrubbing system for controlling level of CO_2 in the storage.
- Ethylene Control Systems: Based on scrubber heated catalyst system where ethylene is oxidized to yield CO_2 and water vapour.

b. MA Storage:

A modified atmosphere can be defined as one that is created by altering the normal composition of air (78% Nitrogen, 21% oxygen, 0.03% carbon dioxide and traces of novel gases) via a package system to provide an optimum atmosphere for increasing the storage length and quality of food/produce.

c. Hypobaric storage Low Pressure Storage (LPS):

Hypobaric storage system is comprised of storing plant material under conditions of reduced pressure along with continuous moist air flow. This system is based on principal of removal of CO_2 and ethylene under reduced pressure conditions. It is important to supply humid air to avoid water loss in cut flowers. Best results are obtained at reduced pressure to 40-60 mmHg. This maintains the quality of the product and considerably prolongs the storage life but is highly expensive method. It is mediated by a vacuum pump which evacuates the container until the desired pressure is reached. The level of all gases is reduced and ethylene diffusion for the product is enhanced. This system is recommended for vegetables, like curing of onion rather than flowers.

9. Transportation and Marketing

- Quick and efficient transportation of flowers at retail end maintaining its optimum flower quality is an important process after application of post harvest handling technology.
- The mode of transportation may be via road, rail, air or ship depending upon the destination and type of flowers to be transported.
- It needs a system approach containing four interacting subsystems, *viz.,* physical process, infrastructure, market information and management during the entire transportation and distribution process.
- There is need to maintain continuous cool chain during the entire transportation process.
- Limited cargo space and high cost of air freight charges are two major drawbacks in export of flowers from India.
- Sea shipment is good alternative but takes long time which is detrimental for the highly perishable commodity like flowers.
- The major four cities dealing with cut flower trade are Amsterdam (Netherlands), Tel Aviv (Israel), Miami (US) and Bogota (Colombia).
- There is need to evolve long term storage techniques for different flowers which can facilitate long term transportation also.
- The main agencies involved in marketing of cut flowers are producers/growers, commission agents-cum wholesalers, retailers-cum-florists and consumers.
- The three marketing channels followed by flower growers are
  a. Producer-wholesaler/commission agent-retailer-consumer

b. Producer-Pre-harvest contractor-retailer-consumer

c. Producer-processor

- The growers can directly bring in their product to the auction centre for open bidding.
- Big corporate sector dealing with hi-tech green house flower produce supply cut flower to different international destinations with their brand names like Eden Flora, Tropical Floritech, Banglore, Deccan Flora, Pune, Navbharat Floritech, Hyderabad, etc.
- The agencies like APEDA provide market information and organizations like BIS, DMI, DFPI help to develop good public relations and improve international trade.

Student Activities:

1. Discuss the steps in post harvest management of rose, gladiolus, marigold & jasmine flowers along with flow charts.

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EXERCISE – 9
PROCESSING OF MEDICINAL AND AROMATIC PLANTS

1. Processing of Medicinal Plants:

Medicinal plants are traded as such in bulk from many developing countries for further value addition in developed countries. The first step in the value addition of medicinal plants bio resources is the production of herbal drug preparations (i.e. extracts), using a variety of methods from simple traditional technologies to advanced extraction techniques.

I. Steps involved in the Processing/Extraction from Medicinal Plants:

1. Size reduction:

- The dried plant material is disintegrated by feeding it into a hammer mill or a disc pulverizer which has built-in sieves.
- The particle size is controlled by varying the speed of the rotor clearance between the hammers and the lining of the grinder and also by varying the opening of the discharge of the mill.
- Usually, the plant material is reduced to a size between 30 and 40 mesh, but this can be changed if the need arises.

2. Extraction:

- Extraction (as the term is pharmaceutically used) is the separation of medicinally active portions of plant (and animal) tissues using selective solvents through standard procedures.
- Such extraction techniques separate the soluble plant metabolites and leave behind the insoluble cellular marc.
- The products so obtained from plants are relatively complex mixtures of metabolites, in liquid or semisolid state or (after removing the solvent) in dry powder form, and are intended for oral or external use.
- Medicinal principles are present in different parts of the plant like root, stem, bark, heartwood, leaf, flower, fruit or plant exudates. These medicinal principles are separated by different processes; the most common being extraction.
- Extraction is the separation of the required constituents from plant materials using a solvent.

Methods of Extraction:

a. Herbal teas, Herbal remedies
b. Drug extracts
c. Aqueous drug extracts
d. Decoctions
e. Infusions
f. Macerates
g. Tinctures
h. Fluid extracts
i. Dry extracts

3. Filtration:

- The extract so obtained is separated out from the marc (exhausted plant material) by allowing it to trickle into a holding tank through the built-in false bottom of the extractor, which is covered with a filter cloth.
- The marc is retained at the false bottom, and the extract is received in the holding tank. From the holding tank, the extract is pumped into a sparkler filter to remove fine or colloidal particles from the extract.

4. Concentration:

- The enriched extract from percolators or extractors, known as miscella, is fed into a wiped film evaporator where it is concentrated under vacuum to produce a thick concentrated extract.
- The concentrated extract is further fed into a vacuum chamber dryer to produce a solid mass free from solvent.
- The solvent recovered from the wiped film evaporator and vacuum chamber dryer is recycled back to the percolator or extractor for the next batch of plant material.
- The solid mass thus obtained is pulverized and used directly for the desired pharmaceutical formulations or further processed for isolation of its phytoconstituents.

5. Drying:

- The filtered extract is subjected to spray drying with a high pressure pump at a controlled feed rate and temperature, to get dry powder.
- The desired particle size of the product is obtained by controlling the inside temperature of the chamber and by varying the pressure of the pump.
- The dry powder is mixed with suitable diluents or recipients and blended in a double cone mixer to obtain a homogeneous powder that can be straightaway used, for example, for filling in capsules or making tablets.

6. Storage:

- Dry extracts are usually very hygroscopic and should therefore be ground, mixed under conditions, which exclude moisture as much as possible.
- Intermediate and end products must also be stored under dry conditions.
- Annealing or sealing of the products in suitable moisture tight synthetic foils has proved a good method for this.

7. Types of Packing Materials:

a) **Glass:** It can be found as several variants such as treated soda glass and non- parenteral.
b) **Metals:** A variety of metals including tin plate (tin coated mild steel), tin free steel, aluminium, aluminium alloys are widely used in packaging,
c) **Plastics:** There are five economical materials for rigid type of containers i.e., those based on polyethylene (PE), polypropylene (PP), Polystyrene (PS), PVC and polyester.

2. Processing of Aromatic Plants:

Important features of Essential Oil:

- These essential oils are the odoriferous steam volatile constituents of the aromatic plants.
- These essential oils are used in perfumery, cosmetic and pharmaceutical industries.
- They are usually present in the aerial parts of plants such as flowers, fruits and leaves.
- Most of the commercial essential oil bearing plants belongs to the families Labitae, Myrtaceae, Rutaceae, Compositae, Rosaceae, Graminae and Pinaceae.
- The essential oil accumulation in a plant depends upon the developmental stage of the concerned organ/plant part.
- The composition of the essential oil also varies greatly with the developmental stage of the plants.

Methods of Essential Oil Extraction:

I. Distillation	II.Expression	III.Solvent extraction
1. Water distillation	1. Sponge expression	1. Maceration
2. Water-Steam distillation	2. Sfumatrice Process	2. Enfleurage
3. Direct steam distillation	3. Pelatrice Process	3. Solvent extraction
• Other specialized distillation		4. Super critical carbon dioxide CO_2
1. Cohobation		
2. Fractional distillation		

I. Distillation:

It is often termed as hydro distillation. Because of water is used in this method. There are mainly three different types of methods of distillation as below:

1. Water Distillation:In this method, the material is completely immersed in water, which is boiled by applying heat by direct fire, steam jacket, closed steam jacket, closed steam coil or open steam coil. The main characteristic of this process is that there is direct contact between boiling water and plant material.When the condensed material cools down, the water and essential oil is separated and the oil decanted to be used as essential oil. The water that is so separated in this process is also used and is marketed as "floral waters" (also called hydrosol or sweet water) - such as rosewater, lavender water and orange water.

Advantage:

1. Permits extraction of essential oil from finely powdered plant materials.
2. Inexpensive, easy to construct and suitable for field operation.
3. Oils from powdered material can be extracted.

Disadvantage:

1. Complete extraction is not possible.
2. Certain esters are partly hydrolyzed and aldehydes tend to polymerize.
3. Water distillation requires a greater number of stills, more space and more fuel.
4. Plant material sometimes burns.

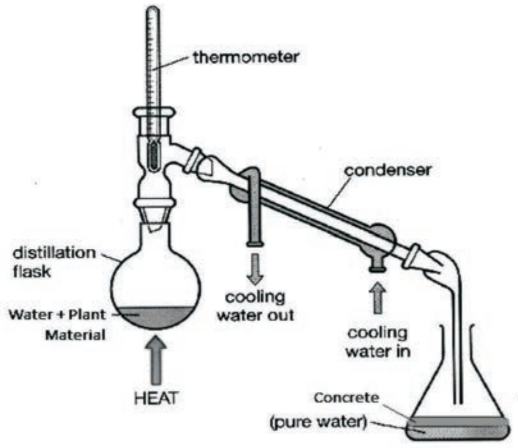

Fig. 1: Water distillation unit

2. **Water- Steam Distillation:**In water and steam distillation, the steam can be generated either in a satellite boiler or within the still, although separated from the plant material. plant material cannot be in direct contact with the fi re source beneath the still; however, the walls of the still are good conductors of heat so that still notes can also be obtained from the thermal degradation reactions of plant material that is touching the sides of the still. A Like water distillation, water and steam distillation is widely used in rural areas. Moreover, it does not require a great deal more capital expenditure than water distillation. Also, the equipment used is generally similar to that used in water distillation, but the plant material is supported above the boiling water on a perforated grid. In fact, it is common that persons performing water distillation eventually progress to water and steam distillation.

Advantages:

1. Higher oil yield.
2. More energy efficient.
3. High oil quality.
4. Volatile oil is less susceptible to hydrolysis and polymerization .

Disadvantage:

1. Requires longer hours of distillation.
2. Plant material of lower portion resting on the grid becomes waterlogged.

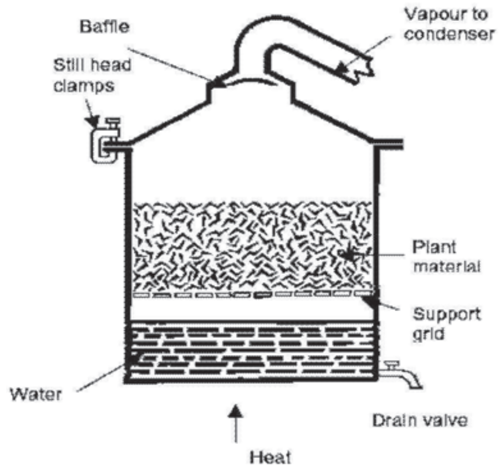

Fig. 2:Water-steam distillation unit

3. Direct Steam Distillation: Direct steam distillation is the process of distilling plant material with steam generated outside the still in a satellite steam generator generally referred to as a boiler. As in water and steam distillation, the plant material is supported on a perforated grid above the steam inlet. A real advantage of satellite steam generation is that the amount of steam can be readily controlled. Because steam is generated in a satellite boiler, the plant material is heated no higher than 100° C and, consequently, it should not undergo thermal degradation. Steam distillation is the most widely accepted process for the production of essential oils on large scale. Throughout the flavor and fragrance supply business, it is a standard practice.

Advantages:

1. Amount of steam can be readily controlled
2. No thermal decomposition of oil constituents
3. Most widely accepted process for large-scale oil production

Disadvantage

1. Much higher capital expenditure needed to establish

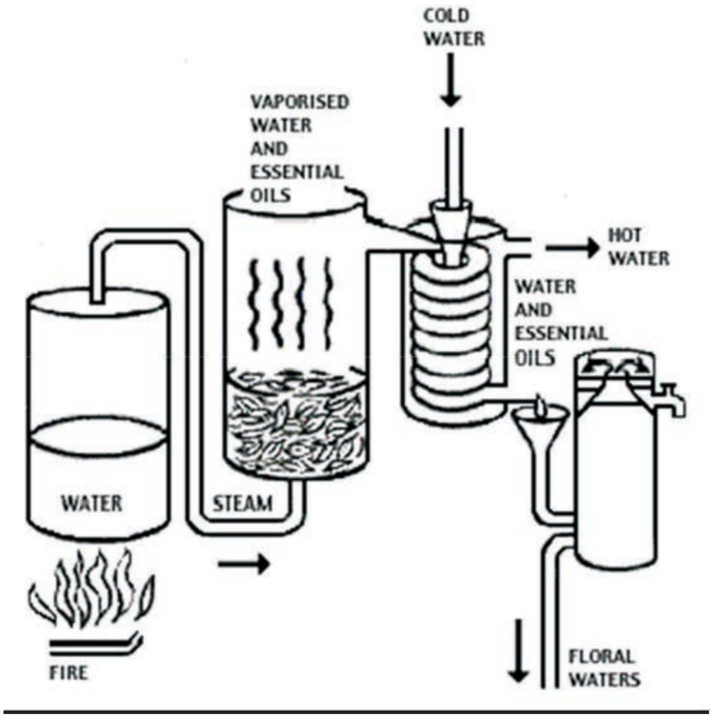

Fig. 3: Direct steam distillation unit

4. **Cohobation:** This technique can be used for water distillation or for water and steam distillation. It uses the process of returning the distillate water to the still after the oil has been separated from it so that it can be re-boiled. This is basically an improvised methodology of the directly fired type steam and water distillation units for oils which have partial solubility in water.

Advantage

1. The oils which have comparatively higher solubility in water are extracted through cohobation. eg: Rose, Lavender and Geranium oil.

II. Expression

Manufacturing of essential oil by means of mechanical pressure to the plant material is basically referred as expression method. No heating of plant material is done during pressing. It is ofently termed as "cold pressed" method. This method was applied earlier exclusively for citrus oil extraction in Sicily.

Characteristics of this method:

1. No heat is required in this method
2. Mostly nuts and oil seeds are extracted using "cold pressed" method
3. Oil is forced from the material under high mechanical pressure
4. Generally produces a good quality oil
5. Citrus oil, orange oil, bergamot oils are also extracted following this method

Three different expression methods are sponge expression, pelatrice process (machine abrasion) and sfumatrice process. These methods are not generally useful for aromatic and medicinal herbage.

III. Solvent Extraction

1. **Maceration:** In this process, crushed plant materials are placed in a closed vessel filled with solvent called menstruum. The system is allowed to stand for seven days, with occasional shaking. Seven days after the liquid is pulled off through a cloth from the solid plant materials (marc). The marc is also pressed to recover as much occluded solution as possible. The strained and expressed liquid thus obtained is mixed (*miscell*) and clarified by filtration.

Principles behind maceration

1. The process of extraction works by molecular diffusion which requires more time.
2. Occasional shaking
   - Assists diffusion
   - Ensures dispersal of solution adhering around the surface of the particles
   - Bringing fresh menstruum to the particle surface for further extraction
3. A closed vessel is used to prevent evaporation of the menstruum during the extraction period

2. **Enfleurage (Cold fat extraction):** In this process flower petals are placed on the fat for a few hours; then repeatedly, the oil petals are removed, and a new layer of petals is introduced. After the fat has absorbed as much fragrance as possible, the oil may be removed by extraction with alcohol. This method was formerly used extensively in the production of perfumes and pomades.

3. **Solvent Extraction:** In this method Soxhlet apparatus is used. Plant material is placed in a thimble-holder, which is filled with condensed fresh solvent. When the liquid reaches the overflow level, a siphon is attached with thimble-holder which helps to unload the solvent it back into the distillation flask, carrying extracted solutes into the bulk liquid. Solute is left in the flask and fresh solvent passes back into the plant solid bed. The operation is repeated until complete extraction is achieved.

Advantages:

1. The displacement of transfer equilibrium by repeatedly bringing fresh solvent into contact with the solid matrix
2. Maintaining a relatively high extraction temperature with heat from the distillation flask
3. No filtration of the extract is required

Disadvantages:

1. Agitation is not possible in the Soxhlet device
2. The possibility of thermal decomposition
3. Time consuming method

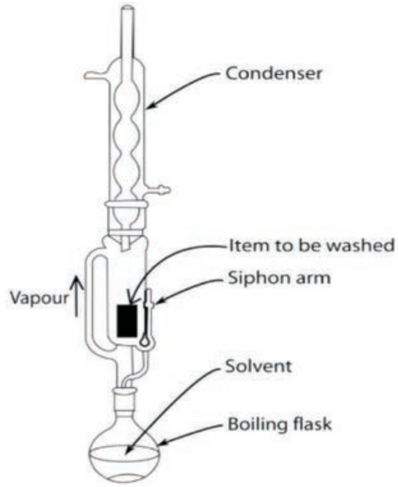

Fig. 4: Soxhlet apparatus

4. **Super Critical Fluid Extraction CO_2:** The process is basically composed of two main sections:

Section I: In this part plant materials come in contact with CO_2. Usually, CO_2 forced towards plant materials at high pressure (P_C=73.81 bar) and high temperature (T_c=31.06 °C). At this condition (super critical) CO_2 turns into fluid form and able the extract essential oil from plant material. A solvent is also used to increase the solubility of essential oil in supercritical CO_2.

Section II: It is known as separator. Separation of essential oil from supercritical CO_2 usually carried out by adjusting the temperature and pressure. Due to the low solubility in supercritical CO2, after recovery of the essential oil the solvent must be recycled and pumped back to the extractor, in order to minimize operating costs.

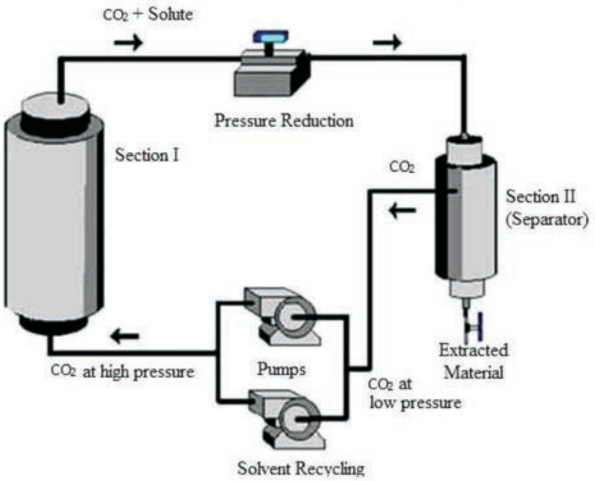

Fig. 5: Super critical fluid extraction CO_2

Student Activities:

1. Discuss the steps in essential oil extraction from Jasmine flowers.
2. Enlist various value added products of MAP.

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EXERCISE – 10
VISIT TO COMMERCIAL FLOWER / MAP UNIT /GARDEN

1. Commercial Flower Unit Visit:

SN	PARTICULARS		OBSERVATIONS/ DETAILS
1	Name of place of visit (Location-Address)	:	
2	Crop Name	:	
3	Variety / Varieties	:	
4	Open or Protected Conditions	:	
5	Climate	:	
6	Soil	:	
7	General practices followed	:	
8	Special Practices Followed	:	
9	Owners View / problems/ Suggestion	:	
10	Harvesting & Yield	:	
11	Marketing	:	
12	Any other observations	:	

2. Medicinal & Aromatic Plant Unit Visit:

SN	PARTICULARS		OBSERVAT IONS/ DETAILS
1	Name of place of visit (Location-Address)	:	
2	Crop Name	:	
3	Variety / Varieties	:	
4	Climate	:	
5	Soil	:	
6	General practices followed	:	
7	Special Practices Followed	:	
8	Owners View / problems/ Suggestion	:	
9	Harvesting & Yield	:	
10	Marketing	:	
11	Processing	:	
12	Any other observations	:	

3. Visit to Garden:

SN	PARTICULARS		OBSERVATIONS/ DETAILS
1	Name of place of visit of garden	:	
2	Type/ Style of garden	:	
3	Focal Point in garden	:	
4	Features in garden	:	
5	Adornments in garden	:	
6	Name of 5 shrubs in garden	:	
7	Name of 5 trees in garden	:	
8	Name of 5 climbers in garden	:	
9	Name of 5 bulbous plants in garden	:	
10	Name of 5 palms in garden	:	
11	Name of 5 annuals in garden	:	
12	Name of 5 cactus & succulents in garden	:	
13	Name of 5 ferns & conifers in garden	:	
14	Type of lawn grass	:	
15	Any other observations	:	

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