Draft Study Material

HYDROPONICS TECHNICIAN

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SECTOR: AGRICULTURE

Grades 12

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NCERT

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION
(a constituent unit of NCERT, under MoE, Government of India)
Shyamla Hills, Bhopal- 462 002, M.P., India
www.psscive.ac.in

Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives. The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material. Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material. This material is copyrighted and should not be printed without the permission of the NCERT-PSSCIVE.

Deepak Paliwal
(Joint Director)
PSSCIVE, Bhopal

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STUDY MATERIAL DEVELOPMENT COMMITTEE

MEMBERS

Dr. Anoop Kumar Rathore, Assistant Professor, Department of Agriculture and Animal Husbandry, PSSCIVE, Bhopal.

Dr. Farooq Ahmad khan, Professor cum chief scientist, Sher-e-Kashmir University of Agricultural Sciences and Technology, of Kashmir

Dr Murtaza Hasan, Principal Scientist, ICAR - Indian Agricultural Research Institute, New Delhi

Dr Neelu Singh ,Scientist -G , Group coordinator research , ICFRE- Tropical Forest Research Institute, Jabalpur

Dr. Ravindra D. Randhe, Scientist (SS), Irrigation and Drainage Engineering Division, ICAR-Central Institute of Agricultural Engineering, Bhopal.

Aman Kumar, Assistant Professor, Department of Agriculture and Animal Husbandry, PSSCIVE, Bhopal.

MEMBER-COORDINATOR

Dr. Rajiv Kumar Pathak, Professor Department of Agriculture and Animal Husbandry, PSSCIVE, Bhopal.

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Module 1
Management of Hydroponic Crops

Module Overview

Hydroponic farming is generally done in protected structures under controlled conditions and has gained immense popularity in recent years due to its numerous benefits. Hydroponic crop management is critical to improving the growth, development, yield and quality of crops. This commences with the sanitisation of the protected structures, growing media and planting material, sowing of seeds/transplanting of seedlings, proceeds with crop maintenance during growth and terminates with crop harvest, storage and distribution. After setting up a hydroponic system, the grower must clean and maintain it for improved crop growth and quality yield.

This module, Management of Hydroponic Crops, provides students with the skills and knowledge to efficiently manage and cultivating crops in a hydroponic system. In Session 1, students will learn the key aspects of managing hydroponic crops, including monitoring growth, nutrient levels, and environmental conditions. Session 2 focuses on the step-by-step process of cultivating various crops within a hydroponic system, from planting to harvesting. In this module also cover the cost-benefit analysis of hydroponic cultivation, helping students understand the economic viability and advantages of this innovative farming method. This module aims to equip students with practical tools for optimizing crop production and ensuring profitability in hydroponic farming.

Some common vegetables grown under a hydroponic system are as below:

1. Leafy vegetables: Spinach, Coriander, Lettuce, Fenugreek, etc.

2. Fruit vegetables: Tomato, Cucumber, Bitter Gourd, Sponge gourd etc.

3. Herbs: Oregano, Mint, Rosemary, Sage, Celery, Parsley, etc.

Learning Outcomes

After completing this module, you will be able to:

- After completing this module, you will be able to:
- Manage hydroponic crop growth by maintaining nutrient balance, water quality, and environmental conditions.

- Cultivate crops in different hydroponic systems by preparing nutrient solutions and optimizing growth factors.
- Analyze the cost-benefit aspects of hydroponic farming and develop a basic business plan for profitability.

Module Structure

- Session 1: Cultivating crops in Hydroponics System
- Session 2: Managing Hydroponic Crops

Session 1: Cultivating Crops in Hydroponics System

Cultivation of Lettuce in Hydroponics System

Lettuce is one of the most suitable leafy vegetables for cultivation under a hydroponic system since it is a high-value salad crop and has a good market demand. It is a short-duration crop which takes 40 – 48 days for maturity. It grows better in cool temperatures and a pH of 5.5 – 6.0, and can be grown in different hydroponic systems such as Nutrient Film Technique (NFT), Ebb and Flow systems and Aeroponics besides the solid substrate systems.

Seedling Preparation

Fig. 1: Growing substrates

Stacking trays in a cool (about 5°C) dark place for 1–2 days helps initiate germination. Once seeds sprout, they are transferred to a greenhouse with temperatures of 15–18°C. Artificial lighting is used for 14–16 hours in the winter months. In regions with high-light intensity, shade curtains (35–40%) are used to protect seedlings.

Prepared seedlings, ready for transplanting, can also be purchased from a reliable, registered and accredited nursery.

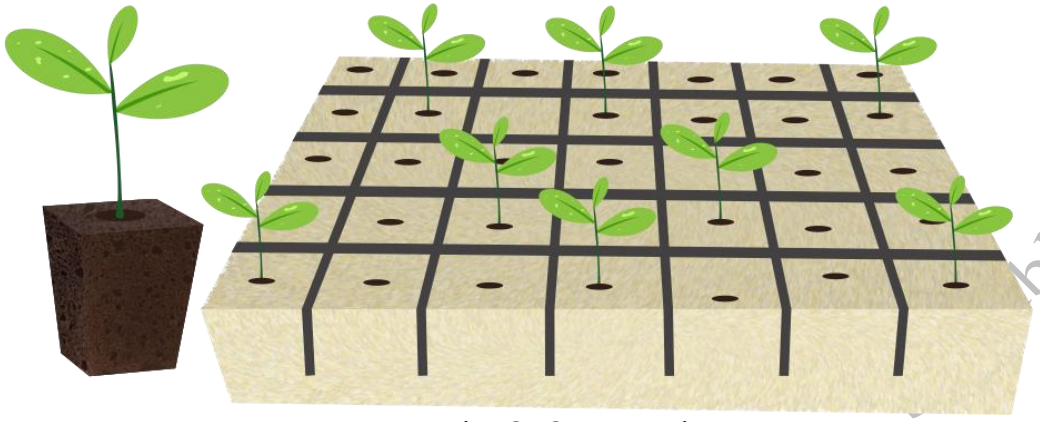

Fig. 2: Starter Plug

Transplanting

Lettuce seedlings are ready for transplanting after 18–25 days (2–3 leaf stage). Transplanting is typically done in the late afternoon to minimize heat stress. Individual seedling units are carefully separated and placed into net pots (with cubes/clay balls) under channels or raft boards, depending on the system used. The roots should be handled gently to prevent damage and reduce disease susceptibility. Ensure the plant base touches the nutrient solution flow, keeping the base moist. After a few days, roots will extend out into the nutrient solution.

Nutrient Solution

Lettuce requires a complete nutrient formulation containing all essential elements for optimal growth and development. Seedlings are fed a half-strength nutrient solution before transplanting (which includes full microelements but reduced macro-elements). Nutrient levels should be adjusted based on the intensity of sunlight and day length. Increased dosage of nitrogen during high-light intensity and long-day conditions, while reduced potassium and nitrogen concentrations under low-light conditions are beneficial. The Hoagland Formulation* for nutrient supplementation is a standard source which can be prepared by any avid Hydroponic technician. However, optimum nutrient solution formulation for hydroponic lettuce cultivation is provided in Table 1:

*The Hoagland formulation is a nutrient solution developed by Dennis R. Hoagland and Daniel I. Arnon in the 1930s. It is widely used in hydroponics and plant nutrition experiments as a standard solution to supply essential nutrients to plants grown without soil.

Table 1: The optimum nutrient solution formulation for hydroponic lettuce cultivation

Name of the nutrient	Quantity required (ppm or mg/l)
Macronutrients	
Nitrogen (N)	158
Phosphorus (P)	44
Potassium (K)	284
Calcium (Ca)	200
Magnesium (Mg)	99
Micronutrients	
Iron (Fe)	5.0
Boron (B)	0.7
Copper (Cu)	0.1
Manganese (Mn)	2.0
Molybdenum (Mo)	0.05-
Zinc (Zn)	0.03

pH and EC Levels

pH and EC (Electrical Conductivity) are two essential parameters in hydroponics and soil science that measure various aspects of a solution's composition. In this, pH indicates the acidity or alkalinity of a solution, while EC measures the concentration of dissolved salts or ions. The optimum pH for lettuce is between 5.5 and 6.0. The EC of most lettuce formulations should be between 1.5 and 2.0.

Relative Humidity

High Relative Humidity (RH), above 70%, can cause tip burn, leading to necrotic leaf margins in lettuce. Hence, RH should be maintained at approximately 60%.

Temperature

Day temperatures should be maintained below 25-28 °C, avoiding fluctuations in air or water temperature.

Light

Lettuce needs 12–16 hours of light for optimum leaf growth and development. During short winter days, the use of Metal Halide (MH) lighting for optimal growth and reducing the cropping time is beneficial.

Pests and Diseases

Hydroponic systems can be susceptible to a variety of pests and diseases. Effective pest and disease control in hydroponics involves good hygiene practices, monitoring for early signs of infestation, and using various control methods like biological controls, organic pesticides, and, if necessary, chemical control.

Lettuce pests include Thrips, Whiteflies, and larvae from moths. Precautions should be taken to exclude these pests from the hydroponic facility by screening the potential entry points and ventilation systems. Biological control methods like pheromone traps, sticky traps are amongst the effective control systems for these pests. Spray of organic formulations viz., neem-based formulations such as Neemo Silver, Neem oil and Bio Neem, etc are recommended for use; however, under severe infestation, spray of chemicals is suggested, although indiscriminate use of chemical pesticides should be avoided.

Cultivation of Tomato in Hydroponics System

Tomato is an important vegetable used in almost all food preparations. Botanically, it is classified as a fruit but is generally served as a vegetable. Hence, it is a potential crop for hydroponic cultivation. Tomato plants grow upto 1-3 meters (3-10 ft) in height and have a weak stem. Tomato is commonly classified as determinate, indeterminate, semi-determinate or vigorous determinate, based on their growth pattern.

Sowing Seeds

It is recommended that quality tomato seedlings, free from pests and disease, may be prepared under a hydroponic system, in protrays in cocopeat. Alternatively, the seedlings may be prepared traditionally under open field conditions. Vermiculite or any other sterile media is sprinkled over the seeds or covers the germination cubes to conserve moisture. Uniform quantity of water is sprinkled over all seedlings at regular intervals to ensure proper germination. Tomato seedlings are generally ready to transplant in 25-30 days.

Transplanting

Tomato has a vigorous growth habit, and hence, it is grown in a substrate system in preference to a water system using nutrient solution. As true leaves (4-5) appear, seedlings are ready to transplant 25-30 days after sowing, at the four-leaf stage. Tomato plants readily grow adventitious roots from the stems. Adventitious roots grow from the bent stem inside the block.

Transplanting into the final growing media should be done before any flowering, and before transplanting, the growing media should be properly leached and moistened. Plants should be irrigated with nutrient solution immediately after transplanting. The spacing of tomatoes under a hydroponic system can be much denser than in soil since tomato plants are trained to grow vertically following a strict pruning schedule.

Light

The lights should be operated to follow a 14 to 18-hour light period per day. If photosynthesis is decreased (due to low light conditions, high humidity or water stress), then the production of sugars declines, and this affects fruit quality and size, making the plant etiolated. During winter months, supplemental light may be required for achieving strong plants.

Temperature

During the seedling stage, tomato needs 20-22°C temperature for proper germination and growth.

After transplanting, the day temperatures for optimum growth of tomato plants should be around 21-26°C and night temperatures should be around 16-19°C.

Humidity

Tomato plants require 80-90 per cent humidity during the day and 65-75 per cent humidity during the night period. Under higher humidity conditions, plants are unable to draw water or nutrients into the roots, which leads to nutrient deficiencies such as blossom end rot (calcium deficiency) and cracking of fruits (Boron deficiency). Misting and fogging systems can be used to increase humidity and decrease temperatures. Exhaust fans and proper ventilation also help in reducing humidity.

Pollination

Tomato is a naturally cross-pollinated crop, but under protected conditions, a grower cannot completely rely on natural air movements for pollination. Thus, at times, other pollinating options such as artificial wind or maintaining honey bee colonies inside the protected structures may be helpful. Insectaries maintained within the protected structure also help pollination.

Nutrient Solution

Optimum macro and micronutrient requirements for tomato plant growth and fruit development are critical factors for soilless cultivation. The concentration of macronutrients in the nutrient solution for tomato needs to be increased with the maturity of the crop, whereas the concentration of micronutrients may remain the same throughout the growth cycle. The concentration of macronutrients in the first stage of growth (from transplanting until the beginning of fruit set) and the second growth stage (fruit set to harvest) is in Table 2.

Table 2: Nutrient Requirements for Tomato (Jensen and Malter, 1995)

Nutrient	**Transplanting to First Fruit Set (ppm or mg/l)**	**Fruit Set to Harvest (ppm or mg/l)**
Macronutrients		
Nitrogen	113	144
Phosphorus	62	62
Potassium	199	199
Calcium	122	165
Magnesium	50	50
Micronutrients		
Boron	0.44	0.44
Copper	0.05	0.05
Manganese	0.62	0.62
Molybdenum	0.06	0.06
Zinc	0.09	0.09

***Note*:** Several experiments have been conducted with the above nutrient formulation for the cultivation of tomato in hydroponics. However, some new varieties may require a different composition of nutrients in formulations. Therefore, it is advisable to consult expert before cultivating new varieties.

pH and EC Level

Tomato plants are best grown in a hydroponics nutrient solution at pH range of 5.5 to 6.5. If pH decreases below 5.0 might cause nutrient toxicity. At higher pH or above 7.0, some nutrients may become unavailable to the plants, resulting in nutrient deficiency.

Tomato varieties perform well with an Electrical Conductivity (EC) between 2.0 and 3.5 ds m^{-1}, although some may require higher target ranges. As fruit-bearing plants, tomatoes demand a nutrient-rich diet.

The EC of the nutrient solution also depends on the growth stage of the tomato. During the earlier vegetative stage, the EC should be approximately 2.0 dsm^{-1}, while at the fruit to maturity stage, it increases to around 2.4 to 3.5 dsm^{-1}. These values may increase if the source water contains significant amounts of salts.

Carbon Dioxide

Carbon dioxide is necessary for the growth and development of plants. Plants can deplete the CO at a very high rate in a closed protected condition. The optimal levels of CO_2, for the tomato crop may be 2 to 5 times the normal atmospheric levels. The growth of the tomato plant is better when its level of CO_2 is between 1100-1500 ppm. It should be injected during daylight, where it is used by plants for photosynthesis. When CO_2, is being injected, the protected structure or greenhouse should remain sealed, the inlet and outlet fans turned off.

Pruning and Staking of Plants

To maintain the structure of tomato plants and support higher fruit yields, it is important to keep the plants upright and strong. Plastic twine can be used to guide the plant's vertical growth and support heavy fruit. Side shoots and suckers should be removed by gently breaking them off by hand to prevent damage or contamination. If the top of the plant dies, a strong lateral shoot can be allowed to grow as the new main stem. Yellowing leaves near the main stem should be removed to reduce the risk of disease. With patience and practice, successful hydroponic tomato cultivation can be achieved. Over time, experience will help in identifying problems and making necessary adjustments to produce high-quality, vine-ripened tomatoes throughout the year.

Management of light for quality plant production

For optimal growth, hydroponic tomato plants should receive 16 to 18 hours of light daily, followed by 8 hours of total darkness. While tomatoes can grow under natural sunlight, their growth and yield may be slower.

Light plays a crucial role in plant development. During the vegetative stage, tomato plants produce leafy growth, which later supports fruit production in the flowering phase. When germinating tomato seeds, continuous light (24 hours) can be provided during the early vegetative stage. As the plants mature, they require a cycle of 16 to 18 hours of light and 8 hours of darkness for proper respiration. LED grow lights are commonly used for hydroponic tomato cultivation.

Practical Exercises

Activity 1

Visit a nearby hydroponics unit to understand the basics management of hydroponics crop.

Materials required:

Pen, pencil, notebook, etc.

Procedure:

1. Plan a visit to the nearest hydroponics unit.
2. Observe and note down following:
    - Crop and variety,
    - Type of hydroponics system used,
    - Nutrient replacement processes
    - Cultural operations
3. Discuss with hydroponics unit owner about plant protection management and monitoring systems.

Activity 2

Demonstrate Setting Up a Small Hydroponics Unit in School

Materials required:

Plastic containers or tubs, Thermocol sheets, Plastic cups with small holes, Plant nutrients, pH and EC testing kits, Grow bags, Growing Media (vermiculite, perlite, coco peat), seedlings (Lettuce, Tomato), Pen, pencil, notebook, etc.

Procedure:

1. **Prepare Water-Based Hydroponics for Lettuce (Deep Water Culture):**
    - Fill a plastic container with water and add nutrients and maintain the desired pH and EC.
    - Cut thermocol sheets to fit the container and make holes to hold plastic cups.
    - Insert lettuce seedlings in the cups, ensuring roots are submerged in the nutrient solution.
    - Place the setup in an area with adequate light and monitor regularly.
    - Monitor the pH, EC, and water levels regularly.
    - Change the nutrient solution of the container if required.
2. **Prepare Media-Based Hydroponics for Tomato (Grow Bag Method):**

- Fill grow bags with sterilized mixture of vermiculite, perlite, and coco peat.
- Place tomato seedlings in the grow bags and water them with a nutrient solution.
- Maintain the moisture of the grow bag.
- Observe plant growth and overall health.

Check Your Progress

Fill in the Blank

1- Lettuce is a _____ duration crop.

2- The optimum pH for lettuce in hydroponics is between _____ and _____.

3- Tomato seedlings are ready for transplanting when _____ leaves appear.

4- The day temperature for tomato plants should be maintained at _____ to _____ °C.

5- The electrical conductivity (EC) range for tomato plants during the fruit-bearing stage is _____ to _____.

Multiple Choice Questions

1- Which hydroponic system is suitable for growing lettuce?
   a) NFT
   b) Aeroponics
   c) Ebb and Flow
   d) All of the above

2- The nutrient solution pH for tomato plants should ideally be in the range of:
   a) 4.5–5.0
   b) 5.5–6.5
   c) 6.5–7.5
   d) 7.5–8.5

3- During the germination of lettuce, the EC of the dilute nutrient solution should be:
   a) 0.5 mS
   b) 1.0 mS
   c) 1.5 mS
   d) 2.0 mS

4- A calcium deficiency in lettuce is most likely to cause:
   a) Tip burn
   b) Chlorosis
   c) Root rot
   d) Powdery mildew
5- Tomato plants require _____ light hours per day during winter months.
   a) 8–10
   b) 10–12
   c) 12–16
   d) 14–18

Subjective Questions

1- Describe determinate and indeterminate growth patterns in tomato plants.
2- Describe the precautions to be taken during the transplanting of lettuce seedlings into hydroponic systems.

Session 2: Manage Hydroponics crops

Care & Maintenance of Hydroponic Crops

Cultivation of crops under a hydroponic system is a specific exercise that requires precision in the management of the crop. Technical expertise is required during the operation of the nutrient and irrigation delivery systems along with the other horticulture practices like training, pruning, staking, etc. In order to maintain a hydroponic system in such a way that can provide a better environment for the robust growth of plants and quality yield, the following points need attention:

1. Selection of suitable crops

Hydroponics is specific to every crop. Hence, the selection of a suitable crop is the first and most crucial aspect of hydroponic farming. High value crops, growing quickly in a short period with minimum maintenance requirements and which are well suited to the market needs of a particular area, are potentially suitable for hydroponic cultivation. Since the establishment cost of an advanced hydroponic system involves a substantial investment, it is essential for agri-preneurs to focus on high-yielding, high-value crops having a substantial market to increase profits. Some potential crops are herbs, viz., celery, parsley, oregano, rosemary, sage, basil; leafy vegetables, viz., lettuce, spinach, kale, Chinese

cabbage, fenugreek, coriander; fruit vegetables, viz., cucumber, beans, tomato, bell pepper, etc. Fruits such as strawberries are suitable for hydroponics. Microgreens are especially successful under hydroponic cultivation since they require a low-maintenance and give a high yield with excellent nutritional qualities, etc.

2. Maintain Conducive Environment

Creating and maintaining an ideal climate specific to the crop being grown is essential for quality production and high yields. The elements of a hydroponic environment are:

- Atmospheric moisture (Relative humidity),
- Temperature, and
- Light.

Regular monitoring and management of these environmental parameters allow growers to produce more crops of better quality effectively. The application of advanced technologies in hydroponic farming systems for the maintenance of optimal conditions within indoor agricultural environments promotes the accelerated growth of crops with high-quality yields.

Automated fan speed controllers are highly beneficial for managing the temperature within grow rooms or indoor farming environments. Such controllers guarantee that the temperature remains within the predetermined setpoint specific to the requirements of the crop being cultivated. An exhaust fan installation might also significantly improve the management of a hydroponic unit by lowering excessive humidity levels within the grow room, besides facilitating pollination where desired.

3. Monitoring nutrient levels

Nutrient scheduling and its monitoring are crucial for the success of any Hydroponics enterprise since the final quality and yield depend on this one factor. Regular monitoring and adjustment of nutrient levels are crucial for ensuring healthy plant growth and maximising crop yields. Nowadays, computerised nutrient scheduling programmes are available which are specific for crops and can achieve the ideal nutrient balance for the different stages of crop growth.

There are numerous ways to monitor the levels of nutrients supplied to the plants, which include AI-based nutrient scheduling programmes, automatic and semi-automated control programmes and through visual observations.

4. Electrical Conductivity (EC):

Salts dissolve in water from the nutrient solutions supplied for the growth of plants. These salts dissociate into their ionic form (NaCl, for instance, decomposes into Na^+ and Cl^- ions) because of which the electrical conductivity of the nutrient solution rises. EC is a reliable indicator of the concentration of salts in the solution. A lower EC indicates a lower salt concentration, while a higher EC indicates a higher salt concentration.

Excessively low values are typically associated with nutrient deficiencies and declining plant growth; excessively high levels of nutrients can cause osmotic stress, ion toxicity, and nutrient imbalance. The most crucial factor in soilless culture is the total salt concentration of the nutrient solution. The EC of a nutrient solution, which is expressed in ms/cm (milli semen per centimetre) or, in some cases, µs/cm, is measured by the Conductivity meter. The µs/cm value can be converted to ms/cm by multiplying it by 1,000.

5. pH Levels

In hydroponics, where plants grow in soilless or water-based nutrient solutions instead of soil, maintenance of the correct pH balance is critical to ensure proper uptake of nutrients by the roots for healthy plant growth. Improper pH levels can hinder nutrient absorption, leading to nutrient deficiencies. The ideal pH range varies from one crop to another. However, a pH range of 5.5 to 6.5 is ideal for most plants. In hydroponic systems, pH testing is essential because it enables farmers to monitor and modify the nutrient solution's acidity or alkalinity.

Deviation in pH is a common error in all hydroponic farming systems. Therefore, it is essential for producers to consistently monitor and correct the nutrient solution pH to ensure optimal crop growth and yields. The primary action in this process is testing of the pH, which is possible through AI-based nutrient scheduling programmes, computer-based automatic and semi-automated control programmes and through visual observations by test strips or a handy pH meter.

Maintain pH in Hydroponics System

- Phosphoric acid / citric acid/ Vinegar: To lower the pH level, or to make the solution more acidic

- Potassium hydroxide or calcium carbonate: To raise the pH level, or to make the solution more alkaline.
- For the maintenance of the pH, chemicals should be added slowly with regular pH monitoring.
- Since any additional nutrients or evaporated water cause a more noticeable change in EC and pH, smaller hydroponic systems require more regular testing.
- Growers can maintain optimal nutrient availability for plants by making necessary adjustments based on routine pH monitoring. Soilless culture requires nutrient solutions with a pH of 5 to 6 (typically 5.5) to maintain a pH of 5.5 to 6.5 in the root environment.

6. Maintain Oxygen levels in nutrient solution

Maintaining required levels of dissolved O_2 in a nutrient solution in a hydroponic system is vital for improved plant health. Oxygen availability to roots grown in soilless culture can become limiting if there is a reduction in root growth rate, ion and water uptake or if sufficient O_2 is not provided. This reduces the performance of the plant, eventually reducing yield and production. Plants raised in a hydroponic system, particularly under high greenhouse temperatures, can rapidly exhaust the dissolved oxygen in the nutrient solution, leading to inadequate root aeration, resulting in a decline of root respiration. A decrease in O_2 level of the soilless medium may result in weaker roots, a rise in pest and disease incidence, and reduced plant growth. The beneficial bacteria that guard a plant from infections and enhance nutrient uptake are negatively impacted by the decreased level of oxygen around the root zone. Oxygen levels in the NFT hydroponic system can be maintained by circulation of the nutrient solutions at regular intervals or by bubbling oxygen through the solution.

7. Regular/Periodic change of nutrient solution/water

Changing water is an essential aspect of maintaining a hydroponics system. Unlike the "set it and forget it" approach, where water is never changed, hydroponics requires regular water changes to ensure optimal plant growth. There are two main approaches to changing water in hydroponic systems: the first is partial changes, and the second is complete changes. All hydroponic systems have a water reservoir, which could be a simple bucket or a separate tank connected to drip lines and hoses in advanced systems. The water in the system depletes or becomes imbalanced over time, requiring periodic topping-off or

partial changes to maintain nutrient balance and water volume. Regular water management is key to maintaining a healthy and efficient hydroponic system.

8. Maintaining Light

Light is an important component for maintaining production. The photo period requirement of the crop being cultivated needs to be maintained for enhanced flowering and fruiting. Similarly, herbs and other foliage vegetables can be maintained in their vegetative or foliage phase just by regulating the duration of light exposure, and this could increase their yield substantially. Light intensity and exposure duration for hydroponic crops significantly affect plant growth and development. However, certain day-neutral varieties of crops such as tomato, bell peppers, cucumbers, strawberries, etc. do not have any particular photo period requirement and are thus, very suited for hydroponic cultivation. Gardeners might implement automated systems to regulate the lighting schedule of 12-16 hours of light for long-day plants and 6-8 hours of light for short-day plants, in a way that all plants receive uniform, adequate light.

9. Specialised operations:

Certain crops require specialised operations such as training, pruning, staking, etc, for optimum production and superior quality fruits. Indeterminate tomato, bell peppers and cucumber, etc, may be staked to grow upright with the help of strings. As the plant height increases, the string can be tightened/ adjusted with the help of a pulley.

Similarly, the excessive foliage growth of the plants can be pruned to optimise nutrient uptake and final production of fruits. The plants are trained to grow upright in order to utilise the vertical space and for harvesting light for maximising fruit production, which takes place on different nodes of the plants.

10. Minimise Pest Infestations

All the hydroponic systems, regardless of the type of crop or environmental conditions, will inevitably encounter pest issues at some point of time. This is because the cultivation is being performed in enclosed spaces, and once any pest is introduced, it multiplies very fast due to the conducive environmental conditions maintained in the protected structures. Implementing appropriate preventive strategies is crucial for managing pests effectively and enhancing the overall management of the hydroponic unit. Common pests that frequently invade grow rooms and hydroponic plants include spider mites, whiteflies, and aphids. Utilising appropriate agrochemicals in the correct amounts is a well-established

method for pest prevention. Additionally, the installation of moving fans and the maintenance of adequate ventilation within hydroponic plant growth rooms significantly contribute to the reduction of pest and mould proliferation.

It is always beneficial to use preventive measures for the introduction of pests rather than their control. Regular sanitization of the Hydroponics facility after the final harvest of the crop is an essential feature for the prevention of pests. Similarly, developing a sanitization zone just before entry to the hydroponics facility, standard sanitization protocols for workers, machines and implements being used, etc., can effectively minimise pest introduction. Fly proofing by nets in open soilless facilities is beneficial. Standard operating procedures should be followed strictly for sanitization of workers and protected structures. Physical control systems, like the use of light traps, pheromone traps, sticky cards, etc., are preferred over the use of chemical pesticides since the latter may result in residual toxicity in the produce.

Common Insect-Pests and Diseases in Hydroponic Crops

Hydroponic farming with its controlled environment and optimized nutrient delivery offers numerous advantages in agriculture. However, like traditional soil-based farming, hydroponic systems are also susceptible to various insect-pests and diseases that can impact crop health and yield. Strategies for prevention of disease and pest infestation in hydroponic systems or minimal use of chemicals is preferred. Understanding the common insect pests and diseases in hydroponic crops is essential for effective management and maintenance of hydroponic systems.

Diseases of Hydroponic Crops

Plant diseases encompass a broad spectrum of conditions that adversely affect growth and productivity of plants. These diseases can be caused by pathogens such as fungi, bacteria, viruses as well as by algae.

a. Fungal Diseases -Fungal diseases are a common threat to plants, causing diseases in a wide range of crop species impacting their growth and yield. Some common fungal diseases are described below:

- **Grey Mould (*Botrytis*):** Grey mould is a common fungal disease caused usually by *Botrytis cinereal.* It affects a wide range of plants, including vegetables, fruits, ornamentals and greenhouse crops. Grey mould typically appears as sooty greyish-white and furry fungal growth on infected green fruits and stems in cool and humid conditions with stale air.

Fig 3. Gray Mold (Botrytis) in tomato

- **Powdery Mildew:** Different plants may be infected with different fungi, causing powdery mildew. Various fungi, in particular, many species of *Oidium, Microsphaera, Podosphaera, Uncinula, Erysiphea and Phyllactinea* cause powdery mildew in plants. It first appears as small white or greyish spots or patches on the upper surface of the leaves and then progresses to a fine pale grey-white powder all over. It aggravates in dim light, cool temperature and high humidity.

Fig. 4: Powdery Mildew disease in lettuce

- **Early Blight:** Early blight is a common fungal disease that affects tomato and potato plants, among others. It is caused by the fungus *Alternaria solani,* especially in the early to mid-stages of the growing season. Dark brown or black spots develop on the lower leaves of the plant. These spots often have concentric rings and may expand in size over time. Leaves may turn yellow around the lesions as the disease progresses. Early blight can also affect the fruits of tomato plants, causing dark sunken lesions that may lead to rotting.

Fig. 5: Early Blight in plant of tomato

- **Fusarium wilt:** Fusarium wilt is caused by various species of *Fusarium,* including *Fusarium oxysporum*. It affects many crops, including tomato, cucurbits (such as cucumbers and melons), bananas, and most of the ornamental plants. It causes stunting, yellowing and wilting of affected plants. *Fusarium* wilt pathogens can persist in soil for long periods, making crop rotation an essential management strategy.

Fig. 6: Fusarium wilt in tomato

- **Root rot:** Root rot is a common and serious fungal disease caused by species of *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Fusarium*. These fungi thrive in poorly drained wet soils and can infect a wide range of plant species, including ornamentals, vegetables and trees. Pathogens infect the root system, causing decay which ultimately leads to stunted growth, wilting and death of plants if left untreated.

Fig. 7: Root rot disease

b- Bacterial Diseases: Bacterial diseases pose significant challenges to agricultural productivity worldwide. These are caused by various pathogenic bacteria that infect a wide range of crops, spreading rapidly under favourable environmental conditions such as high humidity, warm temperatures and overcrowded planting conditions. Some common bacterial diseases are described below:

- **Bacterial wilt:** Symptoms of typically include wilting and yellowing of leaves starting from lower parts of the plant and progressing upwards. As the disease advances, the entire plant may wilt rapidly which leads to death of whole plant. In some cases, vascular tissues may exhibit brown discolouration. Additionally, plants may show signs of stunted growth, reduced vigour and eventual collapse.

Fig. 8: Bacterial wilt in lettuce

- **Bacterial Spot:** Symptoms often include formation of small water-soaked spots on leaves which later on dries forming cracked lesions surrounded by yellow colouration. Disease development is most prevalent during warm and moist conditions.

Fig. 9: Bacterial spot in lettuce grown in NFT

c. Viral Diseases: These diseases are caused by various pathogenic viruses that infect a wide range of crops. Viruses can spread through multiple avenues including insect vectors, contaminated seeds and mechanical transmission. They disrupt normal cellular functions of the plant leading to symptoms such as leaf mottling, yellowing, stunting, necrosis and deformities in infected plants. Some common diseases caused by viruses are described below:

- **Tomato Yellow Leaf Curl Virus (TYLCV):** TYLCV is characterized by symptoms such as yellowing and upward curling of leaves, stunted growth and reduced fruit production. Infected plants may also exhibit leaf thickening, vein swelling and overall vigour decline. TYLCV is particularly problematic in warm and humid climates with high whitefly populations. The virus can spread rapidly in fields and greenhouse environments leading to severe yield losses and economic consequences for farmers.

Fig. 10: Tomato Yellow Leaf Curl Virus

d. Algae: Algae are a diverse group of photosynthetic organisms that can be found in various aquatic and terrestrial habitats. These can range from microscopic single-celled organisms to large multicellular forms like seaweeds. The proliferation of algae is triggered by stagnant water, abundant moisture and light exposure. However, algae themselves do not directly harm plants, they compete for nutrients and can affect EC of the growing environment in hydroponics system and hence need to be managed.

Integrated Disease Management (IDM)

Integrated Disease Management (IDM) involves the timely use of various combined measures to reduce the pathogenic invasion. This involves site selection and

preparation, altering the planting practices, use of resistant cultivars, modifying the environment, pruning, thinning, shading, etc., and use of pesticides, if required. Along with this, following conventional techniques, monitoring environmental factors, disease forecasting and establishing economic thresholds are also important. The disease incidence can be minimised or eliminated by adopting the following tactics.

Plant pathogens (fungi, bacteria, and viruses) can serve as a major source of inoculum. Clean cultivation means the removal of crop residues from the hydroponics unit, keeping the channels clean to minimise pest population in the hydroponics system. Resistant varieties of crops provide one of the most successful approaches to the control of plant pathogens in many crops, especially those that cannot be controlled by other means. Some cultivars are resistant to a particular disease and are, therefore, inherently less damaged than other genetically related plants growing in the same area. Most of the seed and soil-borne diseases, such as damping off, wilt, rots, dieback, anthracnose, etc., attack the crop through seed or soil. Seed treatment reduces the chances of infection. High density in a hydroponics system may increase the incidence of many diseases. Infections can move easily from diseased to healthy plants in a dense field. It is, therefore, desirable to plant the crop with proper spacing. Uprooting or pruning of diseased plants or parts so that the infected plants or parts do not transmit pathogens to healthy ones. Training and staking the crop helps the plants so that their leaves do not come in contact with the soil and thereby controlling infection or infestation. Erecting nets, sticky bands and mechanical traps control insect vectors that may transmit viruses.

Chemical or a combination of chemicals lethal to the fungi that saves the host from infection is called a fungicide. Fungicides, according to their movement in the plant system, are of two types. The first one is systemic, which when applied to plants, dissolves in the cell sap and is effective for the whole plant irrespective of where it is applied. For example, benlate, carbendazim, metalaxyl, thiobendazol, propiconazole, etc. The second one is a contact fungicide whose action is restricted to the area of the plant where it is applied. The examples are sulphur, mancozeb, zineb, etc. Seed treatment is a simple way to avoid infection in the soil and the seed. Generally, seeds are treated @ 2.0–2.5 g of fungicide/kg of seed. A seed dressing drum or earthen pitcher can be used for treating the seeds. Fungicides used are carbendazim, carboxin, oxathin, etc. The aerial parts affected by foliar disease can be controlled by the foliar sprays of the fungicidal formulations. Specialised sprayers are available for the treatment. Generally, fungicides are sprayed along with compatible insecticides. This reduces the cost

of the application. These fungicides are sulphur, copper oxychloride, maneb, zineb, nabam, etc. Before planting, seedlings and cuttings are dipped in the fungicidal solution for a certain period to avoid infection. The solutions could be carbendazim, maneb, sulphur, zineb, etc.

Insects of Hydroponic Crops

Hydroponic crops are generally free from insect infestations as they are grown in a controlled environment. However, once introduced harmful insects increase to infiltrate the growing area. Since conducive environmental conditions for growth are being maintained in the structures, hence insect population also multiplies rapidly unless managed in time. These insects feed on plant foliage, resulting in different symptoms that ultimately result in crop loss and poor quality.

Insects	Details
1- Leaf Hopper or Jassids  *Fig. 11: Leaf Hopper or Jassids*	Leaf hopper or jassids (*Amrasca biguttula)* nymphs and adults are green and move diagonally when disturbed. They suck the sap from the leaves, leaving them yellow and curling upwards. In severe conditions, the leaves become brown, dry and fall down.
2- Aphids  *Fig. 12: Aphid*	Aphids or *Aphis gossypii* are soft bodied insects. They are also known as plant lice. The tiny insects may be green to black in colour and are found in a cluster on the tender parts of the plant. Tomato aphid adults are fragile, slender and minute with fringed wings. They harm the crop constantly by sucking sap from the lower leaves and the tender shoots of the plant. Aphids exude honey dew, which attracts ants and develops a sooty mold. The leaves curl up. Aphids act as a vector for transmission of disease-causing viruses.

3- Whiteflies  *Fig. 13: Whiteflies*	Whitefly or *Bemisia tabaci* adults are white tiny scale-like insects covered with a white waxy bloom. Nymphs and adults both feed on the upper surface of the leaves by sucking cell sap. The affected parts of the plant show yellowing and wrinkling of leaves. It is a major vector for transmitting leaf curl viral disease
4- Leaf Miner  *Fig. 14: Leaf Miner*	Leaf miner larvae are orange yellow and apodous. Maggots enter the leaf and eat the mesophyll of the leaves by making tunnels and zigzag structure on the leaves. Removal and destruction of the severely infested leaves is an effective control
5- Thrips  *Fig. 15: Thrips*	*Scirtothrips dorsalis* and *Thrips palmi* are minute insects with fringed wings. Both adults and nymphs damage the crop and lacerate leaf tissues and curl the leaves inwards. This incidence is severe during dry periods.

Integrated Pest Management (IPM)

Integrated pest management (IPM) is an efficient and economical approach to controlling pests in crops. It makes use of virtually all methods of pest control, including natural pesticides, beneficial insects, special cultivation practices, and even chemical pesticides in the right measure at the right time. Routine agronomic practices can help in minimising pest infestation by slight modification in the timing or method of their application. These functions are preventive methods. The field operations, right from field preparation to harvesting or post-

harvesting can reduce the population of one pest species or the other, are listed below:

1. Grow insect and disease resistant varieties recommended for specific regions.
2. Destroy unwanted stubble after the crop is harvested.
3. Change in sowing or planting time aimed to disturb the synchrony between the host and pest populations.
4. Nutrients should be applied in a balanced manner.
5. Excessive use of nitrogenous fertilisers should be avoided since they intensify the incidence of sucking pests.
6. Excess use of water should also be avoided as humidity increases pest population. Reducing pest population with the help of devices that influence them physically or adjust their physical environment.
7. Manipulation of temperature, humidity and light is used for this purpose.
8. Use of light traps, pheromone lures, hot water treatment, etc.
9. Use insect traps to monitor or directly reduce the population of insects. In this method visual lures, chemical attractants, sticky bands and pheromones are installed to attract insects. Use pesticides judiciously, that is, the right pesticides, in the right amount, at the right time, in the right place.
10. Apply chemical pesticides only when other effective methods are not available.
11. Choose less toxic and less persistent pesticides.

Precaution Taken During Hydroponics Cultivation

In hydroponic cultivation, balanced nutrient formulation is important, as plants rely entirely on water-based solutions for their nutrition. Regular monitoring of pH and EC levels ensures that nutrients are available in the precise amounts for healthy plant growth. The water used in the system must be free from contaminants like pathogens, chemicals, salts, and sediments. A filtration system is crucial to maintain clean water. Environmental factors such as temperature and humidity should also be carefully controlled to provide optimal growing conditions. Additionally, light intensity and duration need to be managed effectively. Supplemental lighting, like LED grow lights, is necessary to ensure plants receive sufficient light for photosynthesis.

Proper maintenance of the hydroponic system is equally important. Regular cleaning of components such as pipes, reservoirs, and pumps prevents algae buildup, blockages, and bacterial growth that could harm plants. Disease

prevention is a priority, requiring sterilized equipment, good hygiene practices, and protection against external contamination, as waterborne pathogens can spread rapidly. Adequate aeration of the nutrient solution is vital to supply oxygen to the roots, preventing issues like root rot. Choosing the right growing medium is also crucial, as it should support plant roots while allowing water and nutrients to flow freely. Regular monitoring and adjustment of water and nutrient levels help avoid imbalances caused by evaporation or plant uptake, ensuring consistent plant health and growth.

Maintain Hygiene

Hygiene is the most important factor. Wearing protective clothes, gloves, and shoes is crucial for the effective management of a hydroponic system to prevent contamination. Moreover, use disinfectants to clean different tools/systems before and after every use to reduce the spread of harmful microbes among crops. Maintaining cleanliness in hydroponic farming is essential for preventing diseases as well as encouraging healthy plant growth. With Farm's Enterprise Resource Planning (ERP) hydroponics package, growers can optimise and gain complete control over indoor farming operations, leading to better management of the hydroponic unit and increased profit.

Cleaning the Hydroponics system

a. **Cleaning the hydroponics system** is an important maintenance practice to ensure optimal plant growth, prevent contamination, and maintain the efficiency of the system. Over time, residue from nutrient solutions, algae, and microbial growth can accumulate in pipes, reservoirs, and growing channels, potentially clogging hydroponic components. Remove and disconnect any parts that are inside or connected to your reservoir (airlines, tubing, pumps, etc.) and drain the reservoir's nutrient solution and clean the interior of the reservoir and channel with a sponge. Make sure to scrub every inch of the walls, work your way around the reservoir, starting at the base. Empty any remaining cleaning agent. Use fresh water (2-3 times) to rinse the reservoir. After cleaning, the hydroponic tank should be dried to ensure that no fibre or other debris is left behind. After cleaning, hydroponic tank should be dried to ensure that no fibre or other debris are left behind.

b. **Visual Observation:** Plant growth and health observations can reveal important information about nutrient excesses or deficiencies. Nutrient imbalances may be indicated by symptoms such as leaf discolouration, stunted growth, or yellowing of the leaves.

Fixed and operational cost of establishment of hydroponic system

Hydroponic systems/area vary according to space, crop type, resource Hydroponic systems/area, and so on. Most hydroponics technology in India is imported and used by affluent members of society who give up the cultivation after a short period of time due to a lack of technical know-how and higher production costs due to the high initial cost of the system and the high cost of nutrient formulation, which is a major impediment to adoption of Hydroponic technology in India.

Establishment of hydroponic system depend upon various factors viz.,

a. types of system being used,
b. size of hydroponics unit,
c. environmental control,
d. location etc.

A protected structure is a prime requirement for hydroponic culture, and it requires grow beds or trays, water pumps, nutrient delivery pipes, lights, reservoir, channel, etc. Any hydroponics setup investment can be grouped as fixed costs and operational costs.

Fixed Cost- These are one-time initial investments for components, structure of the hydroponic system. These are mostly stable but are essential for the setup and infrastructure of the system. They include the purchase of hardware such as hydroponic grow systems, pumps, air circulation systems, reservoirs, channels, irrigation control setups, lights, and construction of the greenhouse or facility. These costs also cover the installation of the system and any one-time labour charges for setup.

Operational costs- These are ongoing expenses that are required to run a hydroponic system efficiently. These include electricity, water pumps, and climate control systems, nutrients, and growing media, costs of maintaining equipment and hiring labour for monitoring, harvesting, and system upkeep. Operational costs tend to vary depending on the scale of production and plant requirements. In a 5000 square feet area, following are requirements and setup cost to start NFT hydroponic farming

Hydroponic System's One-Time Setup Cost	
Polyhouse shelter	₹ 6,00,000/-
Pipes (4 inches)	₹ 7,00,000/-
Pipes (2 inches)	₹ 12,000/-

Pipe connectors	₹ 1,20,000/-
Stand platform for 40 stands (holds 32 pipes each)	₹ 1,00,000/-
Tank (20000 litres)	₹ 55,000/-
Plastic tanks – 2 (1000 litres)	₹ 15,000/-
Plastic tank (5000 litres)- INR 22000	₹ 22,000/-
Water pump(1-HP)- 4 pumps	₹ 30,000/-
Water pump (0.5-HP)- 2 pumps	₹ 10,000/-
Net cups- 20000 plus	₹ 1,00,000/-
Water cooler	₹ 60,000/-
RO system	₹ 50,000/-
pH meter-	₹ 1,200/-
TDS meter-	₹ 2,000/-
Labour cost-	₹ 10,000/-
Total one-time cost	₹ **1,88,7200/- to 20,00,000/-**

Hydroponic System per cycle cost A hydroponic farming system can give a yield every month. Hence, recurring costs per cycle or monthfor hydroponic farming of lettuce are computed as follows:	
Electricity	₹ 15,000/-
Seeds-	₹ 20,000/-
Fertilizers	₹ 20,000/-
Labour	₹ 10,000/-
Maintenance	₹ 5,000/-
Packing and transportation	₹ 10,000/-
Total per cycle cost	₹ **80,000/-**

Hydroponic Farming Profit – On a 5000 square feet area, the following are the projected one-time yields of crops like Lettuce	
Total production	3,200 kg
Waste	1,000 kg
Total left	2,200 kg
Value in the market	200 INR/kg
Value of yield	₹ 4,40,000/-
Profit Margin	
Profit margin = Total earnings per cycle - per cycle investment	
Profit margin= 4,40,000 – 80,000 = 3,60,000 INR/cycle	

The margin of profit per cycle or month	₹ 3,60,000/-
Total margin of profit per year (per cycle × 12)	₹ **43,20,000/-**

Source : "Hydroponic vegetables: A sustainable food production system and profitable venture under climate change." : *Indian Horticulture*

Practical Exercises

Activity 1

Demonstrate different cultural operations in hydroponic unit.

Materials required:

Pen, pencil, notebook, hand lens, etc.

Procedure:

1- Observe the following:

- Plant growth and its health
- Root development
- Insect pest and disease.
- Nutrient deficiency symptoms
- Take corrective measures as per need.

Check Your Progress

Fill in the Blank

1- Maintaining dissolved _____ levels in a nutrient solution is important for healthy plant growth in hydroponics.

2- Cleaning the hydroponics system prevents _____ and maintains system efficiency.

3- The electrical conductivity (EC) of a nutrient solution is measured in _____.

4- Powdery mildew disease first appears as small white or grayish spots on the _____ of leaves.

Multiple Choice Questions

1- Fusarium wilt is caused by:

a) Viruses
b) Bacteria
c) Fungi
d) Algae

2- Early Blight is characterized by:

a) Yellowing leaves
b) Root decay
c) Circular lesions with concentric rings
d) White patches on leaves

3- Bacterial wilt causes:
a) Root decay
b) Dark lesions on fruits
c) White mold on stems
d) Yellowing and wilting from lower leaves

4- pH of the nutrient solution is measured using:
a) pH meter
b) EC meter
c) Thermometer
d) Litmus paper

5- Root rot is caused by:
a) Low light intensity
b) Excess oxygen
c) Poor drainage and wet soils
d) Nutrient imbalance

Match the Following

Column A	**Column B**
1. Gray Mould	A. Botrytis cinerea
2. Electrical Conductivity	B. Indicates salt concentration
3. Fusarium Wilt	C. Caused by *Fusarium oxysporum*
4. Phosphoric Acid	D. Lowers pH in nutrient solutions
5. Exhaust Fans	E. Reduce humidity in grow rooms

Subjective Questions

1- Describe common Insect-pest and diseases of hydroponics crops and their management.

2- Explain precaution taken during hydroponics crop cultivation.

Module 2
Harvesting and Post-Harvest Management of Hydroponic Produce

Module Overview

Harvesting and post-harvest management of hydroponic produce are important stages to ensure the quality and shelf life of produce. Harvesting, especially in a Hydroponic system, requires careful handling to avoid damaging delicate plant roots and stems, often involving tools designed to make clean cuts. Harvesting at the right stage preserves ocular, nutrients, and visual appeal. Once the crop is harvested, produce needs immediate post-harvest care, typically including precooling, washing, cleaning, trimming, sorting, grading, packaging, labelling and transportation of the harvested produce. Hydroponic produce is susceptible to moisture loss and temperature sensitivity; hence, providing controlled storage conditions is helpful to maintain the freshness of produce.

This module, Harvesting and Post-Harvest Management of Hydroponic Produce, focuses on the best practices for harvesting and handling hydroponic crops to maintain quality and extend shelf life. In Session 1, students will learn about the proper techniques and timing involved in harvesting hydroponic crops, ensuring optimal yield and quality. Session 2 covers the crucial steps in post-harvest handling, including cleaning, packaging, and storage, to preserve the freshness and nutritional value of the produce. This module aims to provide students with comprehensive knowledge to effectively manage hydroponic crops from harvest to the consumer market.

Learning Outcomes

After completing this module, you will be able to:

- Explain the process of harvesting, including the best practices for timing and techniques to ensure crop quality.
- Describe post-harvest handling methods to maintain freshness, reduce losses, and improve market value.

Module Structure

- Session 1: Maturity indices and Harvesting
- Session 2: Post-Harvest Handing

Session 1: Maturity indices and Harvesting

Harvesting and post-harvest management of hydroponic produce are important stages to ensure the quality and shelf life of produce. Harvesting, especially in a Hydroponic system, requires careful handling to avoid damaging delicate plant roots and stems, often involving tools designed to make clean cuts. Harvesting at the right stage preserves ocular, nutrients, and visual appeal. Once the crop is harvested, produce needs immediate post-harvest care, typically including precooling, washing, cleaning, trimming, sorting, grading, packaging, labelling and transportation of the harvested produce. Hydroponic produce is susceptible to moisture loss and temperature sensitivity; hence, providing controlled storage conditions is helpful to maintain the freshness of produce.

> The time of harvesting of produce depends on several factors such as storage facilities, availability of market, transportation facilities and distance of market/ final destination to get the desired quality attributes, and their resistance or tolerance to withstand handling and processing.

Maturity of crops

Maturity at harvest is an important parameter to ensure product quality, the rate of quality changes during postharvest handling and the shelf life of intact produce. It affects postharvest tolerance for handling and processing operations, and their post-harvest life. It is recommended to harvest hydroponic produce at the optimal maturity stage, not only because of the economic benefits for producers but also because the physiological response of vegetables/fruits during refrigerated storage allows optimal quality maintenance with respect to plants harvested earlier or later than the optimal maturity stage. Maturity at harvest can significantly impact product composition and the nutritive value of the produce.

Harvest maturity indicators

Harvest maturity indicators help determine the optimal time to harvest, ensuring quality, flavour, ocular, nutritional value, and storage potential. The following are some common maturity indices/indicators for vegetables/fruits:

- **Colour:** The primary criteria for harvesting of crops/vegetables. Mostly it depends on the ocular observation of the harvester. Colour charts have been standardised and are available for cultivars, such as spinach, lettuce, cucumber, carrot, tomato, chilli, etc.

- **Shape /Size:** The shape of fruit can change during maturation and can be used as a characteristic to determine harvest maturity. The changes in the size of fruit are an important indicator to determine the time of harvest.
- **Aroma:** Some vegetables/fruits synthesise volatile chemicals as they ripen. Such chemicals give vegetables/fruit their characteristic aroma and can be used to determine maturity, e.g. mint, basil, etc.

Three physiological stages of produce to be harvested are represented by different signs of quality -

- **Maturation**: The fruit or vegetable is fully developed in size/shape.
- **Ripening:** Overlaps maturation, indicated by colour/taste.
- **Senescence:** Last stage, represented by natural degradation of the vegetable as in loss of texture, flavour, colour, etc.

- **Firmness:** Vegetable/ Fruit may change in texture during maturation, especially during ripening, when it may become rapidly softer. Excessive loss of moisture may also affect the texture of crops. These textural changes are detected by touch, and the harvester can simply check by touch or gently squeeze the fruit and judge whether the crop is ready for harvest.

Maturity indicators vis-à-vis the time of harvesting of different crops:

Category	Criteria	Crop	Maturity/harvest indicators
Leafy vegetables	Leaves should be: • A uniform dark green should be fully turgid • fairly clean and free from serious damage • fresh and crisp. • free from discolouration, yellowing, blemishes, and decay	**Spinach**	• Spinach or other leafy vegetables are considered mature on the basis of size and quality of leaves. • For the second harvest, generally 3-4 weeks of regrowth are required.
		Lettuce	• Maturity depends on the number of leaves, size and head development. • Standard size: 3-6 inches, depending on varieties (A very loose or easily compressible head is immature, and a very firm or hard head is over-mature).

Fruit-bearing crops/ vegetables	Colour, Shape /Size, Aroma and Firmness are important criteria	**Tomato**	• Mature green tomato /whitish green in colour, at colour break stage, and very firm, they will, in time, soften somewhat and turn orange-red in colour. • Vine-ripe may be considered breaker stage or ripe stage, where the tomato is just showing the red colour on the bottom. • The time of harvesting of tomatoes depends on the type and distance of the market from the cultivation site.
		Cucumber	• The size of a mature cucumber may vary (6-8 inches) depending on variety. • Cucumbers should be harvested at an immature stage. • The colour can range from light to dark green, with no yellow colour. • Yellow colour indicates the cucumber is over-mature.
Root crops	Leaf quality/condition of leaves often determines the maturity/time of harvesting of vegetables. Generally, the optimum harvest time	**Carrot**	• Carrots should be ready for harvest about 60-80 days after planting, depending on the variety. • The tops of the carrot roots will be about 3/4 to 1 inch in diameter. They will also be vibrant in colour.

	for root crops is considered when leaves become pale yellow and dried	**Potato**	• Size determines the grade of potatoes in the market. • It is a short-duration crop and matures in 100-120 days. • The dying of the aerial part of the potato plant, also known as vine senescence, indicates the maturity of the potato.

Tools for Harvesting and collection of produce

Effective harvesting techniques are essential to ensure the quality and freshness of produce. Using the right tools avoids damage, increase efficiency, and reduces labour cost, besides ensuring proper handling and care. Some important tools are:

1. **Pruning Shears / Secateurs**: Sharp, clean shears are vital for cutting fruits and vegetables without damaging the plant.
2. **Sharp Knife**: A small, sharp knife can be useful for larger plants or roots.
3. **Harvesting Buckets/Plastic crates/Baskets**: Use lightweight containers to collect harvested produce, makes transport easier. These containers should be smooth without any sharp edges that could damage the produce. The containers are available in a variety of materials such as paper, polyethylene film, sisal, hessian, or woven polyethylene and are relatively cheap but give little protection to the crop against handling and transport damage. However, for perishable products, these are not suitable due to risk of contamination besides damage of produce by getting crushed when the sacks are stored one on top of another or during handling and transportation.
4. **Harvesting Trolley or Cart**: Helps transport larger quantities of produce efficiently from harvesting site to storage or packaging site.
5. **Labels and Markers**: For identifying different varieties and tracking harvest dates.

6. Scale: To weigh produce for inventory or sale purposes.

Fig. 16: Pruning Shear

Fig. 17: Sharp Knife

Fig. 18: Harvesting Bucket

Fig. 19: Scale

Fig. 20: Harvesting Trolley and Cart

General guidelines for harvesting and handling practices

- Harvesting of the crop should be done at a suitable ripeness stage, depending on the market which is being targeted. Vegetables which are to be transported to distant markets should be harvested at physiological maturity so that they ripen by the time they reach the market. Besides this, the damage would also be reduced since vegetables are more firm at this stage and do not get crushed during transit. For local markets, ripened vegetables can be harvested since they are to be consumed immediately.
- Harvested produce should be handled with care to minimise mechanical damage. Mechanical damage affects the quality of produce, allows for disease organisms to enter and affects the market value of the produce.
- To reduce harvest losses due to microbial contamination, handling and harvest tools, containers and utensils should be cleaned and properly sanitised regularly. Cutting equipment should be sharp to prevent damage to the plant. Workers should be trained on how to use sharp knives and shears safely to prevent needless injuries.

- In hydroponics/soilless cultivation, water used to supply different nutrients is recirculated in the system. This nutrient solution/water can serve as a vector for cross-contamination during harvest, since it may come into contact with the harvestable produce through dipping, splashing, dripping, hands or harvest tools getting wet. Therefore, care should be taken during harvest to minimise contact of water/nutrient solution with the harvestable produce as well as the harvester.
- During cutting crops at the base, do not cut into solid substrate such as peat moss or rockwool, to avoid contamination of the harvesting tools or the produce.
- Harvesting and handling should be done with care to prevent damage to the petioles of cucumber, tomato, etc. and leaves of lettuce, mint, coriander, etc.
- Bunching ties should not be too tight, as crushed or split petioles may lead to rapid decay.
- Damaged plants/produce should be discarded carefully during and after harvest to minimise microbial contamination to the remaining produce.
- The produce should be moved to the packaging, handling, and cold storage area as soon as possible after harvesting.
- Harvest containers should be on a raised surface, and never placed on the floor or ground.
- The vehicles used for the transportation of produce should also be cleaned properly. Since fruits and vegetables are perishable, refumigated vans are preferred to maintain the quality and freshness of the harvested produce.

Harvesting of produce in Hydroponics: Dos and Don'ts

Leafy greens, including herbs, grown using nutrient flow, deep flow, ebb and flow, or vertical technologies, are at higher risk of contamination compared to crops grown in top feeder systems because of the chances of direct contact of the product with the production water. Additional care should be taken during harvest to prevent contamination by pathogens that may be in the nutrient solution.

Dos	Don'ts
• Wear clean gloves to harvest and place produce in clean and sanitised containers.	• Don't touch harvested produce directly. • Avoid contact with water/nutrient solution from

• Disinfect all tools and equipment that come in contact with produce. • Train harvest personnel in the proper way to harvest the crop to minimise damage and waste during harvest. • Minimise mechanical damage- avoid drops, throwing, and rough handling. • Package produce in strong containers depending on the nature of the perishability of the crop. • Move the produce to the packaging, handling, and cold storage area as soon as possible after harvesting.	produce to keep the produce free from contamination. • During cutting crops at the base, do not cut into solid substrate such as cocopeat, peat moss or rockwool. • Do not pick up produce that has fallen onto the ground during harvesting. • Do not use any chemical treatments that are not specifically recommended or approved.

Grading of produce for marketing

Grading is an important operation for fetching a suitable price for the produce. Fruits, vegetables or foliage of different grades attract different customers and hence, can be sold at different prices.

The best quality of produce is generally graded as 'Grade A'and can fetch a premium price since it is consumed in High-end Hotels/restaurants and is readily purchased by elite society ready to pay premium prices for good quality. Similarly, the culled or discarded fruits or vegetables, which are Graded C, can be sold in the local markets rather than being discarded. Marketing of the harvested produce as a mixed lot generally fetches an average price, affecting the overall economics of production, and thus, is not recommended.

After harvesting of hydroponically produced produce, it should be graded based on size, colour, shape, weight, and appearance. Grading ensures marketing of quality produce, enhances value as it fetches better prices, consistency, and customer satisfaction. Grading also helps to minimise waste and spread of disease-causing pathogens.

Electronic Record Keeping

Maintaining records is an important aspect of running any hydroponic system smoothly. Hydroponic crops are very sensitive; hence, managing them becomes

difficult for growers if they have not maintained proper records. The hydroponic system needs to record various things such as the dose of nutrient solution, time of application, date of solution replacement, pH, EC, Total Dissolved Solids (TDS) level, and CO_2 level, among other factors. Nowadays, various software is available to help maintain records online so that growers can access it from anywhere.

Practical Exercises

Activity 1

Visit to a Hydroponics Unit and Demonstration of the Harvesting Process of Different Crops

Materials required:

Pen, pencil, notebook, secateurs, trays, etc.

Procedure:

1- Visit the hydroponics unit and observe the crops being grown.
2- Identify crops that are ready for harvesting.
3- For leafy greens:
   - Pull out whole plant and clean the roots and leaves.
   - Use scissors to trim stems above a growth node to allow regrowth.
4- For fruiting crops:
   - Gently twist or cut fruits like tomato or cucumber to avoid damaging the plant.
5- Place the harvested produce carefully into trays or baskets to avoid bruising.
6- Pack the harvested produce for marketing.

Check Your Progress

Fill in the Blank

1. Maturity indicators such as _____, _____, _____, help to determine harvest time.
2. Tools used for harvesting of hydroponics produce are _____and _____.
3. Harvesting tools and containers must be sanitized to prevent _____.
4. Bunching ties should not be too tight to prevent damage to _____.

Multiple Choice Questions

1. Harvesting hydroponic produce at the optimal maturity stage ensures:
   a) Larger size

b) Faster growth
c) Quality and economic benefits
d) Longer roots

2. Which is NOT a post-harvest step?
   a) Sorting
   b) Precooling
   c) Washing
   d) Weeding
3. Carrots are ready for harvest when roots are _____ in diameter.
   a) 1-2 inches
   b) 3-4 inches
   c) 3/4 to 1 inch
   d) 5-6 inches
4. After harvesting, hydroponic produce should be:
   a) Left in sunlight
   b) Stored in cold storage
   c) Sprayed with water
   d) Packed loosely in woven baskets

Match the Following

Crop	Maturity Indicator
1- Spinach	**a-** Whitish green, firm, breaker stage or red at bottom
2- Lettuce	**b-** Tops of roots 3/4 to 1 inch in diameter, vibrant colour
3- Tomato	**c-** Number of leaves, size, and head development
4- Carrot	**d-** 3-4 weeks of re-growth, based on size and quality of leaves
5- Potato	**e-** Vine senescence, aerial parts dying

Subjective Questions

1- Describe the sign of maturity in leafy vegetables.
2- Explain harvesting techniques of hydroponics crops.

Session 2: Post-Harvest Handling

The postharvest handling of hydroponically grown produce is similar to that in traditional cultivation practices. Postharvest handling is important to maintain the quality and shelf life until it reaches the consumer. The major steps used for post-harvest handling of hydroponic crops are:

Precooling:

Precooling is a process that involves lowering the temperature of freshly harvested fruits and vegetables to reduce spoilage and extend their shelf life. It is an important part of the post-harvest cold chain that helps to remove field heat, reduce respiration rates and slow down the growth of spoilage organisms, ensuring superior quality of the perishable fresh produce for a longer duration. This, in turn, helps to extend the marketing duration of the product.

Washing and Cleaning

Even though hydroponic systems use water and nutrient solutions instead of soil, there can still be particles of dirt, debris, or residues from the nutrient solution present on the surfaces of the vegetables. For washing of vegetables, use cool running water for rinsing and gently rub the surfaces to remove any visible dirt or debris or soak in water in a clean bowl or basin for a few minutes to ensure all contaminants are washed away. This can help loosen any remaining residue. The following are the steps to remove dirt, debris, or residues in various produce:

- **Leafy greens, broccoli, and cauliflower**: Soak these vegetables in a bowl of cold water for 5 to 10 minutes to remove dirt from crevices.
- **Berries, herbs, or tomatoes:** Use a sink sprayer to wash these delicate or soft produce. Place the produce in the colander and turn it while spraying with cool water.
- **Root vegetables:** Scrub potatoes, carrots/ turnips with a soft brush under lukewarm running water.

Cleaning

Before packaging/storage of produce, cleaning is an important step to ensure that produce is free from grow media, debris, and damaged plant matter. For crops like cucumbers and tomatoes, brushing the surface can help remove any remaining dirt after washing. In air cleaning, compressed air can be used to blow off loose debris or dust from crops, particularly those sensitive to excessive water.

Drying

The produce must be dried properly so that there are no water droplets adhering to the leaves or fruit surface. These could be a potential source for microbes which could cause spoilage and rotting during storage and transportation.

Trimming

Trimming is the removal and cutting of all undesirable leaves/stems/ stalks/ roots/other non-edible or unmarketable parts. Trimming enhances visual quality, minimises water loss and other deteriorative processes. Trimming is done especially in vegetables and flowers to remove unwanted, discoloured and rotting (e.g., cabbage, cauliflower, spinach, lettuce, etc.) or parts that may favour deterioration or damage during later handling. Trimming also reduces the unnecessary transportation cost of that part of the produce which is non-marketable and has to be discarded before it reaches the consumer

Sorting

Sorting of the produce is done primarily to remove vegetables which are unsuitable for the market or storage due to damage by mechanical injuries, diseases, etc., so that they do not cause spoilage in the harvested produce. Secondly, the harvested fruit is segregated on the basis of maturity into physiologically mature, mature or over-mature fruits so that they can then be dispatched to a suitable distant market for the former two or to the local market for the over-mature fruits where they would fetch a better price without any spoilage losses.

Sorting is generally carried out on the basis of their physical properties, such as their size, shape, colour, and weight. It is done manually to sort the fruits and vegetables into the different categories described above.

Grading

The process of sorting is closely associated with grading which once again separates produce according to colour, shape, size, absence of disease or damage, and volume in order to attain a better market price. Nowadays, machines are also available for grading of produce. Grading contributes to increased market value, improved marketing, longer shelf life, safe packaging and delivery, and the removal of contaminants.

Maturity Indices Indicators

- **Size:** Uniformity in size ensures better visual appeal.
- **Colour**: Natural colour represents freshness and quality.
- **Shape:** Regular, intact shapes are preferred (e.g., straight cucumbers, round tomatoes).
- **Weight:** grading should be done to make uniform-sized lots, also crucial for packaging and pricing.
- **Surface**: Smooth, blemish-free surfaces.
- **Maturity:** Produce should be properly ripened, i.e. neither under- nor overripe. Based on ripeness, they may be dispatched to different market locations.
- **Defects:** Remove damaged vegetables having cracks/ spots/ pest damage.

Produce may be graded in different categories

- **Grade A:** Perfect size, shape, and appearance, suitable for premium markets.
- **Grade B:** Slight imperfections, acceptable for most markets.
- **Grade C:** Visible defects, suitable for processing or local markets.

Packaging

Packaging of produce reduces the wastage of commodities by protecting them from mechanical damage, dirt, moisture loss and other undesirable physiological changes and deterioration due to microbes/insects, etc., during storage, transportation and subsequent marketing. For providing uniform quality to packed produce, the commodity should be carefully supervised and sorted before packaging. Packaging cannot improve the quality, but it certainly helps in maintaining it as it protects produce against the hazards of the journey. Striking developments are reported in the field of packaging of produce and gunny bags, grasses and stem leaves used so far for packaging are now being replaced by a variety of containers such as corrugated fiber board boxes, wooden boxes, baskets woven from bamboo or twigs, sack/jute bags etc. there is a provision that every container in which any fruit product is packed shall be so sealed that it cannot

be opened without destroying the licensing number and the special identification mark of the manufacturer displayed on the top or neck of the container.

Fig. 18: corrugated fiber board boxes

Labelling

Labelling hydroponic produce is essential for ensuring transparency and consumer confidence. Effective labels should include key information such as the product type, origin, and harvest date. Certifications, like organic/hydroponically grown, will enhance the market value of produce. The clear storage and handling instructions should be mentioned for maintaining quality during transportation. Additionally, using durable materials ensures that labels remain intact and legible throughout the supply chain.

Transportation

Distance and mode of transportation affect the quality of produce till it is delivered to the consumers. Fruits and vegetables that require careful handling (tomato, capsicum, cucumbers, etc.) are transported in cardboard or wooden boxes that provide sufficient rigidity to protect the fruits from damage. To transport root crops (beets, carrots, potatoes, etc.), wooden containers, mesh or film bags made of polymer materials should be used. Highly perishable berries and leafy vegetables require special handling and are placed on special racks, in wooden boxes or other rigid containers, which eliminate the possibility of damage during transportation.

Storage

Proper storage of hydroponic produce is vital to maintain freshness, flavour, and nutritional value. Hydroponically grown items have higher water content, making them more susceptible to spoilage. Storing produce in a cool, dark place helps slow down deterioration and retain crispness. Using breathable bags or containers can prevent moisture buildup and mould growth. Additionally, proper

storage extends shelf life, reducing food waste and ensuring that consumers enjoy the full benefits of their hydroponic harvest. This practice ultimately promotes sustainability and healthy eating. The following techniques have been used for storage.

Ethylene absorbents like $KMnO_4$ lining or pouches may be placed in the storage containers to delay the ripening process during storage. Besides this, Modified Atmosphere Storage (MAS) or Controlled Atmosphere Storage (CAS) is also developed to provide suitable $N:O:CO_2$ gasses in a storage environment with the objective of enhancing storage life.

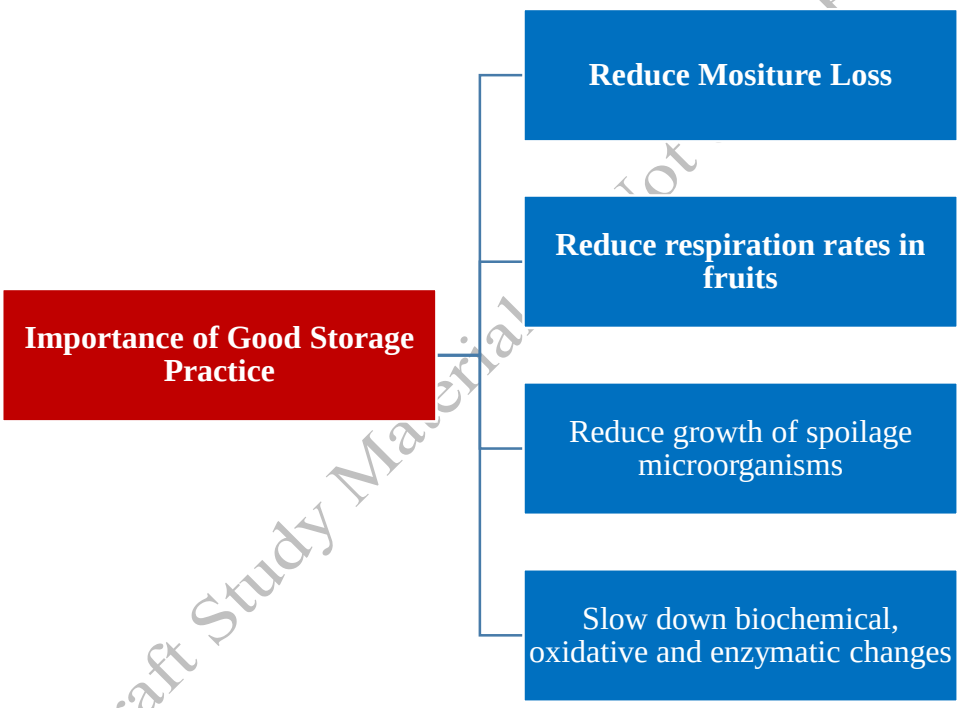

Fig. 19: Importance of Good Storage Practice

Different Method of Storage

1. Low temperature storage

It is a simple storage method for hydroponic produce to maintain freshness, shelf life, and significantly enhance the quality and longevity. The temperature of the cold room depends on the nature of the vegetables/produce to be stored.

- **Leafy greens-** (lettuce and spinach) temperature requirement- 0°C to 2°C with high humidity to prevent wilting.

- **Herbs-** (mint, basil and cilantro) temperature requirement 1°C to 4°C and should be wrapped in damp paper to retain moisture.
- **Fruiting vegetables-** (cucumber, tomato and Chilli) temperatures requirement -7°C to 10°C to avoid chilling injury.
- **Root vegetables–** (potatoes, radishes and carrots) temperature requirements same as leafy greens.

2. Storage at Controlled Atmosphere/ Modified Atmosphere Packaging

The storage at controlled atmosphere is an advanced technique for preserving hydroponic produce by the management of the levels of oxygen, carbon dioxide, and humidity in the storage room. The reduction of oxygen levels and increase in carbon dioxide slow down respiration and ripening processes, significantly extending shelf life. The freshness and nutritional value of leafy vegetables can be maintained for a longer period while controlled atmosphere storage minimises spoilage and preserves the flavour of fruits/vegetables. This technique is also helpful to reduce the wastage of produce, making it a sustainable option for producers.

Cold Chain and Its Importance for Hydroponic Produce

The storage of hydroponically grown produce in a cold environment is essential to maintain the quality and freshness. The distinct temperature specifications are required for different types. Leafy greens such as lettuce and spinach are harvested and promptly refrigerated to 0-4° C to preserve their crisp texture and nutritional quality. By implementing a precise cold chain for each type of hydroponic produce, growers can ensure that their products reach consumers in optimal condition, minimising waste and enhancing overall quality.

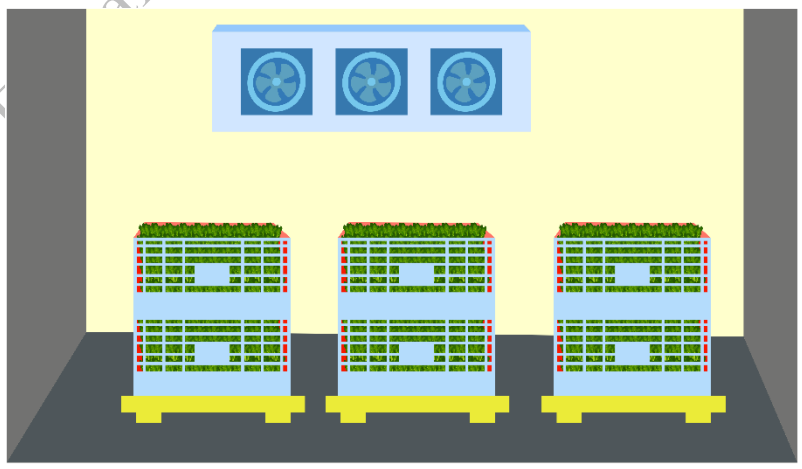

Fig. 20: Cold Storage

Vegetable	Temperature required
Leafy greens and herbs	0-4°
Fruit crops	between 2 and 5° C
Cucumbers	ideally around 7-10° C
Root crops	0-4°

Importance of Cold Chain in Hydroponics:

1. Hydroponically grown produce is often harvested at peak freshness. A cold storage/chain helps to maintain the quality by slowing down the respiration and enzymatic processes that can reduce spoilage.
2. The temperature control in a cold room, according to the nature of produce, can significantly extend the shelf life of hydroponic crops and also reduce waste and ensure high-quality products for consumers.
3. The controlled temperature helps to maintain the quality of produce. It helps to preserve nutrients- vitamins and minerals, ensuring that consumers receive the full health benefits.
4. Cold storage reduces the risk of microbial growth and foodborne illnesses, which is particularly important for leafy greens and other sensitive produce/crops.
5. A reliable cold chain can enhance a producer's reputation and market value of produce by providing quality produce to the consumers.
6. With a controlled environment, produce can be transported over longer distances without compromising quality, opening up new markets for hydroponically grown produce.

Humidity Control

Humidity is also an important factor which directly impacts the freshness and shelf life of hydroponic produce.

Humidity requirements for different produce –

- **Leafy greens-** 90 to 95% to prevent wilting and maintain crispness.
- **Herbs**: About 85% is required to avoid decay.
- **Fruiting vegetables:** Around 70% is required to minimise moisture loss without promoting mould growth

- **Root vegetables:** About 80 to 90% is required to maintain firmness and crunchy texture.

Perforated packaging

Perforated/breathable packaging is important for proper ventilation for gaseous exchange in storage areas to maintain humidity levels, thereby preventing the risk of mould and spoilage, preserving the quality and longevity of hydroponic crops. Perforated packaging helps in retaining moisture, allowing excess ethylene gas to escape, preventing decay, preserving flavour and minimising condensation. Perforated packaging enhances the quality and shelf life of hydroponic produce and maintains the freshness of the produce for a longer period.

Vacuum Sealing

Vacuum sealing provides an airtight microbes-free environment that enhances the freshness and longevity of various hydroponic crops, significantly extending the shelf life of produce by removing air. This process minimises oxidation and slows down spoilage, making it ideal for different produce by checking wilt or decay, moisture loss, and maintaining flavour, texture and crispness

Coatings of hydrocolloids

Natural polysaccharide-based biodegradable edible films are used for coating of produce to enhance freshness and shelf life. These coatings also prevent moisture loss and microbial growth, maintain crispness and nutritional quality. These coatings help to slow down respiration and oxidation, preserving the flavour and texture of produce during storage. The hydrocolloid coatings provide an innovative solution for maintaining the quality of various hydroponic crops during storage.

Post-harvest losses in hydroponic produce

Post-harvest losses in hydroponics refer to the deterioration in quality and quantity of crops after they have been harvested, leading to reduced market value, nutritional content, and economic viability. Hydroponic crops, like other perishable plant produce, are susceptible to post-harvest deterioration. The quality and quantity of the hydroponic produce may be affected due to several factors, including the wrong method and time of harvesting, improper handling, storage, packaging and transportation. Proper management of post-harvest processes is crucial to prevent spoilage, maintain freshness, and preserve the

high-quality standards associated with hydroponically grown produce. Addressing post-harvest losses in hydroponics is essential not only for reducing waste but also for maximising the profitability and sustainability of this innovative agricultural system.

Factors Contributing to Post-Harvest Losses in Hydroponic Produce

- Method and time of harvesting
- Mechanical injuries/damage
- Temperature and humidity mismanagement
- Moisture loss and dehydration
- Poor Hygiene Practices
- Quality and Nutritional Deterioration
- Pests/Rodents and Disease

Practical Exercises

Activity 1

Demonstrate the Process of Grading of Produce

Materials required:

Pen, pencil, notebook, Fresh produce (e.g., fruits, vegetables, or herbs), Weighing machine, Baskets or trays, etc.

Procedure:

1- collect freshly harvested produce for grading.
2- Clean the produce to remove dirt or debris, if necessary.
3- Sort the produce based on:
    - Size: Use a ruler or visually inspect for uniformity.
    - Weight: Use a weighing scale to categorize by weight.
    - Colour: Group produce with similar colour and ripeness.
    - Shape: Separate produce with deformities from those with ideal shape.
4- Remove any damaged or spoiled items during the grading process.
5- Place the graded produce into labelled baskets or trays based on the grade (e.g., Grade A, Grade B).

Activity 2

Demonstrate the Process of Packaging and Storage of Produce

Materials required:

Pen, pencil, notebook, Fresh produce (e.g., fruits, vegetables, or herbs) , packaging material, labels and markers, Storage area, etc.

Procedure:

1- Collect the graded produce for packaging.
2- Select appropriate packaging material based on the type of produce (e.g., plastic pouches for herbs, cartons for fruits).
3- Pack the produce carefully to avoid damage:
   - Arrange items in layers with cushioning if needed.
   - Ensure ventilation holes in packaging for perishable items.
4- Weigh and label the packages with details like weight, grade, and date of packaging.
5- Store the packaged produce in a suitable environment:
   - Use cold storage for perishable items to maintain freshness.
   - Keep non-perishable items in a dry, well-ventilated area.
6- Monitor the storage conditions regularly, such as temperature and humidity.

Check Your Progress

Fill in the Blank

1- The process of lowering the temperature of freshly harvested produce to reduce spoilage is called _____.
2- _____ cooling uses cold water or brine to cool produce like carrots and lettuce.
3- Removing undesirable leaves, stems, or roots to enhance visual quality is known as _____.
4- The method of storage involving the management of oxygen, carbon dioxide, and humidity is called _____.
5- _____ cooling uses a fan to pull cold air through crates of produce for rapid temperature reduction.

Multiple Choice Questions

1- Which of the following is NOT a method of precooling?
   a) Hydro cooling
   b) Ice cooling
   c) Room cooling
   d) Sun drying
2- Which technique uses liquid nitrogen or solid CO2 for rapid cooling?
   a) Hydro cooling
   b) Cryogenic cooling
   c) Vacuum cooling

d) Ice cooling

3- What is the main purpose of trimming hydroponic produce?
   a) To remove dirt and debris
   b) To maintain nutritional value
   c) To enhance visual quality
   d) To increase weight

4- What is the main role of edible hydrocolloid coatings on produce?
   a) Prevent microbial growth
   b) Add weight
   c) Enhance colour
   d) Reduce cost

5- Which step in post-harvest handling involves separating produce by size, shape, and colour?
   a) Grading
   b) Cleaning
   c) Sorting
   d) Labelling

Match the Following

Column A	Column B
1- Precooling	a) Reduces spoilage
2- Vacuum cooling	b) Moisture removal at low pressure
3- Perforated packaging	c) Gaseous exchange during storage
4- Cryogenic cooling	d) Liquid nitrogen or solid CO2

Subjective Questions

1- Explain commonly practiced post-harvest operation in hydroponics.
2- Describe importance of cold chain for fruit and vegetables.

Module 3
Basic Marketing Activities by Small Enterprises

Module Overview

Hydroponics as a commercial venture is a cost-intensive enterprise since the infrastructure cost is high, along with high running expenses. Proper marketing of the hydroponically grown produce is a critical aspect since return on investment becomes an important consideration for the enterprise to be remunerative. With the current emphasis on the commercialization of agricultural production, attention to proper agricultural marketing becomes a high priority. Marketing encompasses activities or goods and services starting from the producer right up to their sale to the actual final consumer. It also denotes the place and region in which buyers and sellers interact freely, as well as the exchange of goods and commodities taking place between them. The value, cost and price of items traded are as per the forces of supply and demand.

This module, Basic Marketing Activities by Small Enterprises, introduces students to essential marketing strategies for small-scale businesses, particularly in agriculture and hydroponics. In Session 1, students will explore different types of markets and marketing channels available for small enterprises, focusing on identifying target customers and selecting the most effective distribution methods. Session 2 covers the process of marketing agricultural produce, including branding, pricing, promotional tactics, and establishing relationships with buyers. This module aims to equip students with the practical skills needed to market products efficiently and boost the success of small enterprises.

Learning Outcomes

After completing this module, you will be able to:

- Identify different markets and marketing channels for agricultural produce.
- Explain the process of marketing agricultural produce, including pricing, distribution, and sales strategies.

Module Structure

- Session 1: Markets and Marketing Channels
- Session 2: Process of Marketing the Produce

Session 1: Market and Marketing channels

Market: The word market is a derivative of the Latin word "*marcatus*", viz., merchandise or trade or a place meant for buying and selling of goods. Therefore, it is the (a) premises where one or more commodities are bought and sold, (b) a meeting place for potential buyers and sellers of a product.

Elements necessary to satisfy the presence and purpose of a market are:

1. Availability of goods or commodities for transactions (physical presence not mandatory)
2. Availability of active buyers and sellers (physical presence not mandatory)
3. Operation of business transactions between buyers and sellers

Classification of Markets

A market is a place where transaction of goods, commodities and produce between buyers and sellers takes place. Agricultural produce passes through several exchanges from one entity to another before it reaches the consumer. These exchanges include assembling, preparation for consumption and dispersion.

- It is rather well known that proper and profitable marketing of any commodity depends on the demand for the product at a given time. The sphere of the market may extend to a locality, village, town, region or a country according to the demand for a commodity. The market may be a physical entity or virtual. Market may be local or global, perfect and imperfect, daily, weekly, monthly or seasonal depending upon their existence and occurrence.

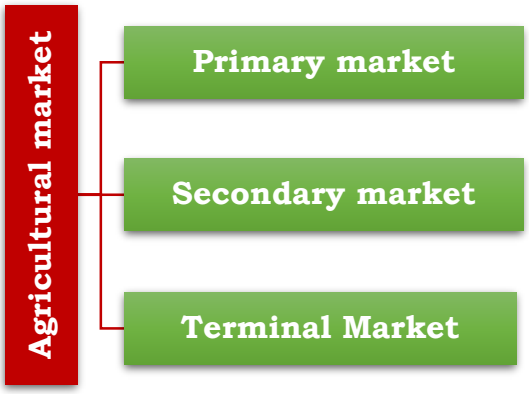

Fig. 21: The various types of agricultural market

1. Primary market

Primary markets are also known as fresh produce markets. Here, the transaction is conducted between the producer and the buyer once or twice a week. The business here involves primary goods or commodities such as food grains, livestock, raw materials, etc. Wholesalers or commission agents abound in these markets, where agricultural produce comes from nearby villages. As per their location, these are often referred to as Village Market**.**

2. Secondary market

In the secondary market, the produce and commodities procured from the primary market are bought and sold. The transactions here are done directly from a seller and by the commission agent or broker (as an intermediary). These are also known as mandis and are situated generally at district or taluka, headquarters or important trade centres near railway stations, and produce is handled in large quantities. Merchants procure products from the primary/wholesale market and bring them to this market for sale.

3. Terminal Market

A terminal market is one that delivers to the actual consumer or exporters. These are generally high-value or high-volume markets, operating on electronic devices or 'over the counter' basis. They are endowed with huge warehouses and storage facilities. There is abundant space for logistics and packaging to provide the material in a finished form. Of necessity, these markets are located in metropolitan cities like Chennai, Mumbai, and Kolkata, being proximate to the port of assembly and loading/shipment. Directly or indirectly, activities of Terminal markets would also influence the activities and operations in primary and secondary markets.

Based on the time span

a) **Daily markets:** The markets which are held only for a few hours in a day are called daily markets. They deal mostly in items of fast turnover or perishable nature (Examples are fish, fresh vegetables, etc.).
b) **Weekly markets:** Held once a week, these are also referred to as "hat". The products and commodities can be stored for some time (The examples are food grains, oilseeds, etc.). The prices are largely governed by local supply and demand.
c) **Seasonal Markets:** These markets deal in commodities of seasonal nature but since different commodities are available in different seasons over a yearly

span, these markets operate almost permanently. The items may or may not be perishable, with facilities for short to medium-term storage.

Market channels

The pathway covering the transfer of title of a commodity is called its marketing channel. It is the route taken by a product in moving from its original owner to the processor and then to the ultimate consumer.

- The participants in the channel vary according to commodity and quantities handled.
- The task of the distribution or market channel system is to match the demand with the appropriate supply.
- All goods go through a series of channels of distribution before being delivered to the final consumer.

There are two main types of channels for the distribution of a market commodity, *viz.,* direct and indirect.

Direct Distribution

In a direct distribution channel, the product or service reaches to consumer directly from the producer or manufacturer. The service sector is the best example of this kind of distribution. In agriculture, such transaction takes place in products which need little or no processing before marketing or in the case of perishable produce like milk and mushrooms, which need to be sold within a specified period.

Indirect Distribution

Indirect distribution occurs when middlemen or intermediaries are involved in the distribution channel. In agricultural produce marketing and distribution, the intermediaries would be the farmer, the local dealer who collects the produce from farmers, the wholesaler (who buys from local dealers) and retailers who sell the produce to consumers. As the number of intermediaries increases in a channel, the price of the product would rise, especially for the final consumer.

Factors governing a product Channel:

1. Nature of the product.
2. Price of the product.
3. Volume or the number of units of sale.
4. Characteristics of buyers and their buying units or the user.

5. Retailers dominate the distribution and sale of low-priced articles with small packaged units.
6. Costly items like Hydroponics system, greenhouse structure, sowing machines, etc., are sold directly by manufacturers or their agents.
7. Public services like gas, electricity and transport are usually sold directly to the consumer.

Important channels of distribution are:

- Producer – Consumer
- Producer – Retailer – Consumer
- Producer – Wholesaler – Retailer – Consumer

1. Producer →consumer

The manufacturer or producer directly sells a product or produce to the consumer; here, the intermediaries are totally dispensed with. Thus, agents or middlemen are not in the picture in this kind of sale. Return on investment is highest for the producer.

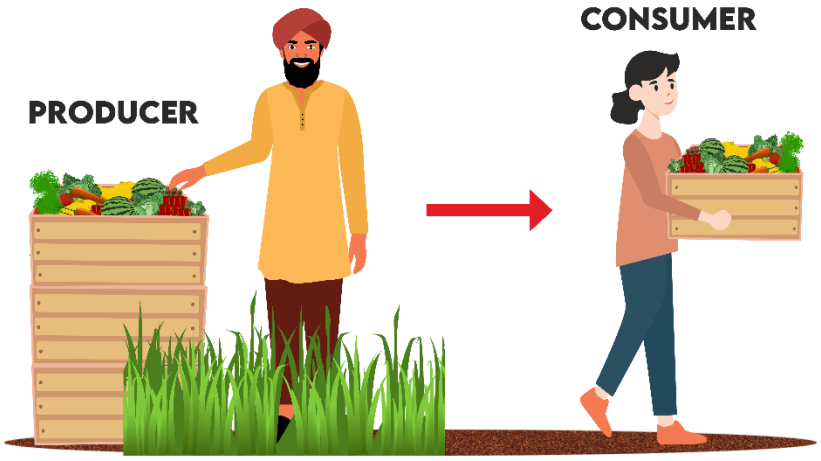

Fig. 22: The market channel process offering produce from the producer to the consumer

2. Producer → Retailer → Consumer

In this channel, producers sell their product to the retailers, and retailers sell it directly to the consumer. This channel works best for farmers to sell their produce to meet their immediate needs, because consumers need more time to decide to purchase it. If storage facilities are not available with the farmer or the seller, it is in their own interest to sell them to a trader before they reach the consumers. This kind of channel is also found beneficial for low volume transactions and

where the assortment of goods and products is broad. The role of intermediaries is vital in establishing a correspondence between demand and supply in the distribution business. In the horticulture sector, producers are often forced to do distress sales to middlemen because of the highly perishable nature of their commodity, lack of knowledge about potential markets or buyers and lack of storage facilities to avoid glut. Hence, the middlemen can earn a larger margin of the profits in this case.

Fig. 23: Market channel having product distributed from the producer to the retailer and finally to the consumer

3. Producer – Wholesaler - Retailer - Consumer

This kind of a long channel is used by manufacturers whose products have an extended or delayed market, viz., clothes, furniture, cutlery, etc. The consumer may take time and try the items, and collect information before making a purchase. This channel is a favorites of the manufacturers of non-food shopping goods.

Fig. 24: The long market channel with products being sent from the producer to wholesaler to retailer and to consumer

Practical Exercises

Activity 1

Enlist the Different Types of Markets and Marketing Channels

Materials required:

Pen, pencil, notebook

Procedure:

1- Enlist the different types of markets where agricultural produce can be sold.
2- Identify and note down various marketing channels used for distributing produce.
3- Describe the characteristics of each type of market, such as:
   - Local Markets
   - Wholesale Markets
   - Supermarkets
   - Online Platforms
4- For each marketing channel, identify the key players involved, such as:
   - Producers
   - Wholesalers
   - Retailers
   - Distributors
   - Logistics Providers

Check Your Progress

Fill in the Blank

1. A market, where commodities are received directly from farmers, is known as _____ market.
2. The prices in a primary market are _____.
3. The prices _____ in a secondary market, depending on the demand and supply of the commodities traded.
4. The intermediaries through which farmers' produce reach consumers are called _____.

Multiple Choice Questions

1. The marketing channel more suitable for custom-made products is _____.
   (a) Producer >Consumers
   (b) Producer > Retailers > Consumers

(c) Producer > Wholesalers > Retailers > Consumers
(d) Producer > Commission agents > Wholesalers > Retailers > Rice mill owners > Consumers

2. Which is also known as fresh produce market?
   (a) Primary market
   (b) Secondary market
   (c) Terminal market
   (d) Seaboard market
3. When middlemen or intermediaries are involved in the distribution channel, it is known as _____.
   (a) direct distribution
   (b) indirect distribution
   (c) direct and indirect distribution
   (d) All of the above

Subjective Questions

1- Distinguish between the following.
   (a) Primary and secondary market
   (b) Daily and weekly market
   (c) Terminal and seasonal market

2- Differentiate between the following.
   (a) Direct and indirect marketing
   (b) Wholesaler and retailer

Session 2: Process of Marketing of Produce

Demand and Supply of the Agricultural Produce

Every farmer is continually chasing his own opportunity for success in a highly competitive market. They aim not only to produce high yields and deliver high-quality crops to the market but also to sell their yield effectively and secure higher profits.

Supply refers to the number of goods or services that producers are willing to offer in the market at a specific price and time. On the other hand, demand refers to the number of goods or services that customers are willing to buy at a particular price and time.

The relation between supply and demand

1.1. The market price of goods or services is determined by the relationship between supply and demand. For example, if a farmer sets a low price for his

product or service, demand is likely to increase. Conversely, if the price is set too high, demand will tend to decrease.

1.2. The market price determines the supply and demand for products or services: The market price influences the supply and demand for products or services. When the market price is high, producers are more interested in offering a certain product or service, leading to an increase in supply. On the other hand, when the market price is low, consumers show greater interest, resulting in higher demand.

A collection of information related to the wholesale and retail price of agricultural produce

The Directorate of Economics and Statistics under the Ministry of Agriculture, Government of India (GOI), is responsible for the collection, compilation and dissemination of the price data of agricultural commodities. The price data is collected in the form of (a) weekly and daily wholesale prices, (b) retail prices of key commodities, and (c) farm harvest prices. The same are explained below:

a) Weekly and daily wholesale prices: Weekly wholesale prices include data for 140 agricultural commodities sourced from 620 markets. The collection of data is the responsibility of price reporters appointed by Agricultural Marketing Committees or the State Governments, and they forward it to the State Directorates of Economics and Statistics. The Directorate of Economics and Statistics, Ministry of Agriculture, GOI receives the prices from various state agencies, forwards it to the Economic Adviser, Ministry of Commerce and Industry, GOI, for closely monitoring wholesale prices.

(b) Retail prices of key commodities: Retail prices of essential commodities are collected weekly from 83 market centres for 88 commodities (49 food items and 39 non-food items) by the staff of the State Market Intelligence Units, State Directorates of Economics and Statistics, and the State Department of Food and Civil Supplies.

(c) Farm harvest prices: Farm harvest prices are collected by the field staff of the State revenue departments for 31 commodities at the end of each crop season and published by the Directorate of Economics and Statistics, Ministry of Agriculture. It brings out a periodical publication entitled Farm Harvest Prices of Principal Crops in India.

Use of the Digital Services

Nowadays, the market is becoming digital, from clothes, food, and machines to services. Digitalization in agriculture is also booming after the pandemic era. There are multiple online businesses running smoothly, a few of which are directly run by farmers or Farmers' Producer Organizations (FPO). Growers are investing a substantial amount in hydroponic setups and going for online business to get better prices for their produce.

E-commerce

E-commerce is the process of buying and selling goods and services over the internet. On an e-commerce platform, customers can order goods or services from anywhere at any time, and those goods and services will be delivered to the consumer. It has various advantages, such as being easy for buyers to select a wide range of products, the right consumer can be targeted, and no physical store is required to run a business which depends completely on networking. In today's era, a lot of e-commerce platforms such as Amazon, Flipkart, BigHaat, and others are available that are popular among customers.

E-commerce for Agriculture

E-commerce can be set up for agricultural produce, where growers can send their produce directly to consumers without any mediator. Through e-commerce platforms, consumers can directly order products from growers and make payments online. E-commerce helps hydroponics growers to sell their produce to target audiences and get a better price for their produce. There are several advantages of e-commerce in agriculture:

- Growers can sell their produce to target audiences without being physically present.
- Growers get better prices for their produce.
- It is easy for consumers to get a wide range of products.
- It is convenient for both buyers and sellers.

Government Schemes for Setting Up the Hydroponic Units

In India, various subsidies and schemes are available from the central and state governments to promote hydroponic farming. National Horticulture Board provides subsidy for hydroponics & and aeroponics farming in India under the initiative "Development of Commercial Horticulture through Production and Post-Harvest Management". Credit-linked back-ended subsidy of 20% of total project

cost limited to ₹25 lakh per project in general states and ₹ 30.00 lakh in North eastern Region, Hilly, and Scheduled regions are also provided.

Additional Support

- **Banks and Financial Institutions:** Some banks offer loans specifically for agricultural projects, including hydroponics. Entrepreneurs can avail loans under schemes such as the Pradhan Mantri Mudra Yojana (PMMY), which provides loans at affordable rates to start their businesses. These loans also offer various subsidies, especially for women entrepreneurs, to support them in starting their ventures.
- **Research Institutions:** Various agricultural universities and research institutions provide technical expertise for hydroponics projects.

Practical Exercises

Activity 1

Visit nearby market and observe different aspects of marketing.

Materials required:

Pen, pencil, notebook

Procedure:

1- Visit a nearby market and observe the marketing activities.
2- Note down the following things:
   - Types of produce being sold
   - Types of sellers
   - Types of marketing channels being used
   - Mode of transportation and logistics used.
   - Mode of payment.
   - Any other information.

Activity 2

Enlist Different Government Schemes and Financial Institutions for Establishment of Hydroponic System.

Materials required:

Pen, pencil, notebook

Procedure:

1- Enlist various government schemes and note down the following observation:
   - Subsidy schemes,
   - Grants, or loans

- financial institutions that provide financial assistance
- eligibility criteria

Check Your Progress

Fill in the Blank

1. Supply refers to the number of goods or services that producers are willing to offer in the market at a specific _____ and time.
2. The market price of goods or services is determined by the relationship between _____ and demand.
3. National Horticulture Board provides a subsidy of _____ of the total project cost for hydroponics farming in general states.
4. E-commerce allows growers to sell their produce directly to _____ without any mediator.

Multiple Choice Questions

1. What is the maximum subsidy offered by the National Horticulture Board for hydroponics in hilly regions?
   a) Rs. 25 lakh
   b) Rs. 20 lakh
   c) Rs. 30 lakh
   d) Rs. 15 lakh
2. What is one of the main advantages of e-commerce for agricultural produce?
   a) Increased transportation costs
   b) Direct selling to consumers
   c) High dependency on middlemen
   d) Limited product range
3. Which factor is NOT a part of hydroponic record-keeping?
   a) Nutrient solution dose
   b) CO_2 level
   c) Wholesale price of produce
   d) pH level
4. How do e-commerce platforms help hydroponic growers?
   a) By reducing product quality
   b) By increasing transportation challenges
   c) By limiting the market reach
   d) By targeting the right audience
5. Which platform is an example of an e-commerce site?

a) BigHaat
b) Google Scholar
c) ICAR Database
d) NABARD Portal

Subjective Questions

1. Explain Relation between Supply and demand.
2. Describe Government Schemes for setting up the hydroponic units.

Module 4
Hygiene, Cleanliness, Safety and Emergency Procedures

Module Overview

Hydroponic or soilless farming is a cultivation technique of agriculture in controlled conditions with 90% less consumption of water in comparison to traditional cultivation practices with soil, in which we can produce quality vegetables/fruits/herbs round the year through the application of nutrient solutions in required composition as per the nature of produce. To avoid any contamination/incidences of pests, etc. in a controlled environment, the cleanliness/hygiene of the field/production area and persons engaged are of utmost importance. As this farming is entirely dependent on the supply of nutrient solutions/water in soilless media, proper maintenance and functioning of machinery with safety measures are necessary to supply proper strength of nutrients with accurate pH, EC and other requirements.

This module, Hygiene, Cleanliness, Safety, and Emergency Procedures, emphasizes the importance of maintaining a safe and hygienic working environment in agricultural settings. In Session 1, students will learn about the safe use of agrochemicals, including handling, storage, and disposal to minimize health and environmental risks. Session 2 covers first aid procedures, treatment methods, and the proper use of safety equipment to address injuries or accidents. Session 3 focuses on the safe operation of agricultural machinery, highlighting safety protocols and preventive measures to avoid accidents. This module aims to equip students with critical knowledge to ensure safety and preparedness in agricultural operations.

Learning Outcomes

After completing this module, you will be able to:

- Explain the safe handling, application, and storage of agrochemicals to minimize risks to health and the environment.
- Describe first aid measures, treatment procedures, and the use of safety equipment for agricultural hazards.
- Demonstrate the safe operation and maintenance of agricultural machinery to prevent accidents and ensure efficiency.

Module Structure

- Session 1: Safe Use of Agrochemicals
- Session 2: First Aid, Treatment and Safety Equipment
- Session 3: Safe Use of Agricultural Machinery

Hygiene of Hydroponic facility to avoid incidence of disease and pests

Hydroponic/soilless cultivation, in a controlled environment, offers potential for sustainable food production with minimum land and water resources. However, like agriculture, hydroponics/soilless cultivation is also susceptible to pest and disease outbreaks. Insect pests such as aphids, thrips, spider mites and whiteflies, etc. as well as diseases like powdery mildew and root rot, can pose significant threats to crop health and productivity since the environment inside the protected structure is being maintained such that it is most beneficial for the crop under cultivation. Hence, the environment would naturally favour the multiplication of disease and pests also.

Types and nature of agrochemicals

Agrochemicals are used to protect crops from insects, diseases and weeds. The incidence of different pests in open field agriculture can significantly reduce the quantity and quality of production. It is documented that annual crop losses could double without the use of agrochemicals. However, in hydroponic/soilless cultivation, incidences of insects, diseases and weeds are very low.

Agrochemicals are broadly classified into natural and synthetic products.

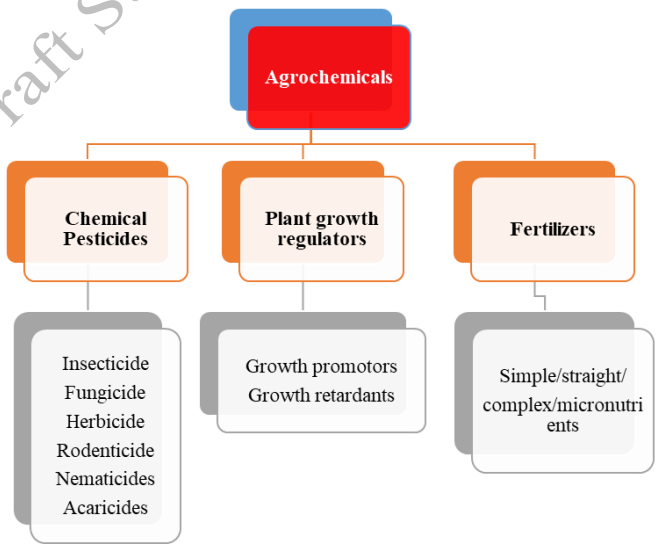

Fig. 25: Types of Agrochemicals

Session 1: Safe use of Agrochemicals

Harmful effects of agrochemicals

Chemical hazards in agriculture are related to the dangerous pesticides being used, as well as the maintenance of plant protection equipment and spraying of pesticides. It has been reported by the WHO that there are three million cases of agrochemical poisoning, with up to 20,000 reported (unintentional) deaths in a year in developing nations. Some of these agrochemicals can be harmless, while others can cause severe to very severe damage to the central nervous system, kidneys, or increase the risk of cancer. Initial symptoms may be variable and misleading, such as muscular weakness, headache, dizziness, and nausea. Continuous use of certain agrochemicals, especially pesticides with which our body comes in contact or is exposed to, results in long-term damage to organs like the kidney, liver, nervous and endocrine system inside our body.

The careless use of agrochemicals has shown various adverse effects, viz., deterioration of nutrient/growing media, pesticide resistance, drug-resistant phytopathogens, posing human health hazard, issues related to bioaccumulation, environmental pollution, etc. Unbalanced nutrient levels and decreased crop-yielding capability are results of their overuse. Some major adverse effects of agrochemicals are-

Effects of agrochemicals on air -The use of agrochemicals in hydroponics has the potential to contaminate air, affecting human and plant health. Agrochemical released into the air can settle to the plant's leaves surface, be broken down by indoor lights/sun light and water in the atmosphere, diffuse with air and altering their composition. These residues/particles of agrochemicals can lead to air pollution.

Effects of agrochemicals on human health- The use of agrochemical can cause several illnesses in humans due to inhalation of polluted air/contact and consumption. Major health hazard is:

- **Acute illnesses:** The typical symptoms of acute pesticide poisoning in humans are fatigue, headaches, body aches, skin discomfort, skin rashes, poor concentration, feelings of weakness, circulatory problems, dizziness, nausea, vomiting, excessive sweating, impaired vision, tremors, panic attacks, cramps, etc., and in severe cases coma and death. Diagnosis of acute pesticide poisoning

Fig. 26: Acute illness

generally occurs when one or more of these symptoms, which appearing a short time after contact with pesticides, are detected.

- **Chronic illness:** The agriculture workers/harvester exposed to pesticides have a significant risk of contracting non-Hodgkin lymphomas and leukemia. The excessive use of pesticides may affect function of different body parts *viz.,* pancreas, lungs, ovaries, the breasts, testicles, liver, kidneys, and intestines as well as brain tumors. The neurotoxic pesticides can also cause developmental neurotoxicity, at much lower exposure levels. Neurological health effects such as memory loss, loss of coordination, reduced speed of response to stimuli, reduced visual ability, altered or uncontrollable mood and general behaviour, and reduced motor skills are general outcomes from pesticides. Other possible health effects include asthma, allergies, and hypersensitivity.

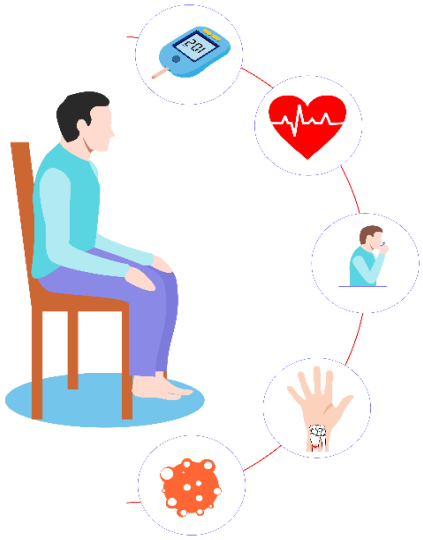

Fig. 27: Chronic illness

- **Water contamination:** The water with nutrients may sometimes be contaminated with agrochemicals There is a suspicion that agrochemicals residues are common in surface water system, especially in irrigation drains, which ultimately pollute the pond and river water, that can harm natural growth of plants or absorbed by the roots.

Fig. 28: Avoid Water contamination

Methods of Safe Use of Agrochemicals

Pesticide application is a major activity in the use of agrochemicals and also the most hazardous. Precautions to be taken, both for the safety of users as well as the general public and the environment. As a grower, it is essential to understand that each product package must comply with standards and regulations specific to agrochemical packaging. The following are the general requirements and guidelines you should follow to ensure safe handling:

- Ensure that the agrochemical packaging is designed to prevent leakage, spillage, or contamination during handling, storage, stacking, loading, and unloading.

- Verify that the Batch Number, Registration Number, and Manufacturing/Expiry Date are marked on the package.
- Check that the materials used for the package, including lids and fasteners, are non-reactive with the contents to avoid any formation of hazardous compounds.
- Repackaging agrochemicals is a specialised task that should only be done by trained professionals.
- Do not transfer chemicals into different containers, even if the new container previously held the same chemical.
- Only authorised individuals should handle repackaging to avoid accidental exposure or contamination.

Storage: Agrochemicals are usually delivered to a store by the supplier or transported by the user. During storage, they are most vulnerable to theft, vandalism, accidental or deliberate misuse or the effects of extreme weather conditions. Users who have to store agrochemicals should know how to construct and maintain a place for storage, thereby ensuring their own safety and that of others. They should also take necessary action to prevent the pollution of the environment.

- Agrochemicals should be stored in a dry and cool place as directed. In very hot or freezing conditions, most agrochemicals would deteriorate and could even damage the containers. Similarly, dampness will weaken paper sacks, possibly resulting in spillage of the contents.
- The storage place should have adequate natural or artificial light by the provision of sufficient window area or artificial (e.g. electric) lighting.
- Windows should not allow direct sunlight to fall onto agrochemicals because ultra-violet light may cause deterioration of containers and contents.
- Electric lights and switches should be positioned to avoid mechanical damage, and there should be an adequate separation distance between lamps and stored agrochemicals to avoid the transmission of heat.
- An extractor fan should be installed to provide adequate ventilation.
- A water supply should be provided nearby, but not in the store. Any water supply used to fill sprayer tanks or animal treatment baths should be so designed as to avoid back siphonage.
- A record should be made of agrochemicals in store but kept separately in a safe place, so that they can be easily accessed in the event of an emergency such as fire or unauthorized use.

- Adequate first-aid facilities should be available to treat minor injuries and contamination of eyes and skin.
- Smoking and the use of a naked flame should be prohibited within the store.
- A suitable fire extinguisher in good working order should be at hand, in case of emergencies.
- Washing facilities should be provided close to the store for anyone who handles agrochemicals. They should be equipped with a wash-basin and clean running water, soap and a towel (disposable towels are best if these are available).
- Separate ventilated accommodation must be provided for protective clothing and personal clothing. This accommodation, which is generally in the form of a cupboard or locker, must not be within the agrochemical storage area.

Disposal of waste chemicals and cleaning of containers

Unused agrochemicals need to be disposed safely. The date of use has expired or is out of date, any damage to the packaging/container, empty containers, spillage clean-ups must be disposed of properly. The following are the general guidelines for safe disposal of waste:

- Agrochemical waste should never be dumped.
- Agrochemicals should never be disposed of to cause any risk to people, animals, crops, water supplies or the environment.
- If possible, waste should be disposed of through an authorized company or person licensed to handle waste disposal.
- Accumulation of waste should be avoided. Waste should be disposed of as soon as possible.
- The worker should read the label on the package or container for any specific advice on waste disposal.
- Empty agrochemical containers should never be reused except possibly, if in good condition, to contain an identical product transferred from a deteriorated or leaking container.
- All containers should always be cleaned thoroughly before disposal. They may be cleaned in accordance with the labelled instructions or, in the absence of instructions, rinse the containers in water successively at least three times.
- Liquid containers should be drained out before cleaning.
- The cleaning should take place when a spray mixture is being prepared so that the drained material and the rinsing liquid can be added to form a part of that mixture.

- The clean containers should be punctured or crushed to make them unusable and stored in a secure place until their disposal is arranged.
- The disposal/burial site should not be near the water body to avoid the risk of pollution to surface water or groundwater.
- The containers should be buried to a depth of at least 1 meter below the surface and below the level of any land drains. There is no risk of seepage from the site, which might cause pollution.
- Protective clothing should be worn during the burial of waste/ handling of hazardous products.
- All the equipment after completion of spraying needs to be cleaned, washed and rinsed. This will produce a relatively large volume of dilute pesticide for reuse or disposal. It should be properly discharged into a sewer connected to a sewage works or the use of a suitable soak-away.

Practical Exercises

Activity 1

Demonstration of Safe Use of Agrochemicals

Materials required:

Gloves, mask, protective clothing, agrochemicals, measuring cup, spray equipment, water, pen, notebook

Procedure:

1. Collect all required materials, and read agrochemical label for instructions and safety precautions.
2. Wear gloves, a mask, and protective clothing, and demonstrate safe handling to avoid spills or exposure.
3. Measure the agrochemical accurately using a measuring cup and mix it with water in the spray equipment as per label instructions.
4. Apply the agrochemical safely using proper spraying techniques.
5. Clean the spray equipment thoroughly after use and proper disposal of containers and leftover solutions.

Check Your Progress

Fill in the Blank

1. Agrochemicals are broadly classified into _____ and _____.
2. The excessive use of pesticides may lead to pesticide _____ in plants and the environment.

3. A major adverse effect of agrochemicals on water is _____ of water bodies.

Multiple Choice Questions

1. What is the primary function of agrochemicals?
   a) Increase soil fertility
   b) Protect crops from insects, diseases, and weeds
   c) Enhance taste of crops
   d) Reduce water usage

2. Which of the following pests is a threat in hydroponic cultivation?
   a) Locust
   b) Grasshopper
   c) Aphids
   d) Ants

3. What should be avoided during the disposal of agrochemicals?
   a) Puncturing empty containers
   b) Dumping waste into water bodies
   c) Cleaning containers three times
   d) Storing waste in a secure location

4. What is a typical symptom of acute pesticide poisoning?
   a) Joint pain
   b) Fever
   c) Hair loss
   d) Excessive sweating

5. What is the depth at which agrochemical containers should be buried?
   a) 1 meter below the surface
   b) 2 meters above the surface
   c) At the surface level
   d) 5 meters below the surface

Subjective Questions

1. What are the first aid treatment measures for chemical poisoning?
2. What protective devices are meant for protection in the agricultural field?
3. Define agro-chemicals.

Session 2: First Aid, Treatment and Safety Equipment

Accidents might happen in spite of all the precautions and care. It is essential for students to know about the immediate medical aid for a chemical accident and to learn about the safety devices needed to prevent accidents.

Common health and safety guidelines to be followed at the workplace

Some basic guidelines for health and safety at work place are as follows:

- Regular sanitization/ of cultivation area/ hydroponic unit is essential to maintain hygiene as well as the health of workers.
- The exposed body parts should be thoroughly washed after use of agrochemicals or before eating/drinking, and after using the lavatory.
- Any cuts or sores on the body should be carefully covered and protected.
- Care should be taken during decontamination or removing protective clothing.
- Always use a soft probe for blowing through sprayer nozzles to unblock them.
- Do not carry contaminated items like dirty rags, tools, or spare nozzles in personal clothing pockets.
- Wash clothes daily, and personal protective clothing separately.
- The fingernails should be short and clean.
- The product that causes an allergic reaction, such as a skin rash, should be avoided.
- Follow the instructions mentioned on the product label.
- The body should be covered with long cloth shirts and trousers, hats, or towels to protect the skin from agrochemicals.
- Workplace i.e., the hydroponic cultivation area, should be cleaned and organized properly to avoid accidents and microbial contamination/growth.
- The hydroponic area should be properly ventilated to prevent the accumulation of harmful fumes/gases, while using chemicals.
- All electrical equipment- air pump, water pump, exhaust fan, cooling device, cables and lights- should be properly maintained and checked regularly. Proper earthing is necessary in the area of soilless cultivation for the proper working of electrical equipment.

Chemical poisoning and first aid measures

Poisoning is the lethal disruption of the body's physiological mechanisms by the consumption/inhalation, ingestion, injection or surface absorption, etc. of toxic chemicals. Immediate first aid measures are very important in these kinds of emergencies. Sources of poison may include insecticides, pesticides, fungicides, herbicides, etc. It can be diagnosed by blood test, Urine test, and also by physical examination of the sufferer.

Chemical poisoning may result from continuous contact or absorption through skin, inhalation of toxic vapour or swallowing it directly. Common symptoms of pesticide poisoning are headache, nausea, vomiting, tremors, convulsions, and difficulty in respiration. A first-aid kit with necessary antidotes should be available at the work site for each type of poisoning. Antidotes are always mentioned on the pesticide containers.

First aid measures for chemical poisoning-

We need to follow the DRSABCD action plan (shown in Fig. 29)

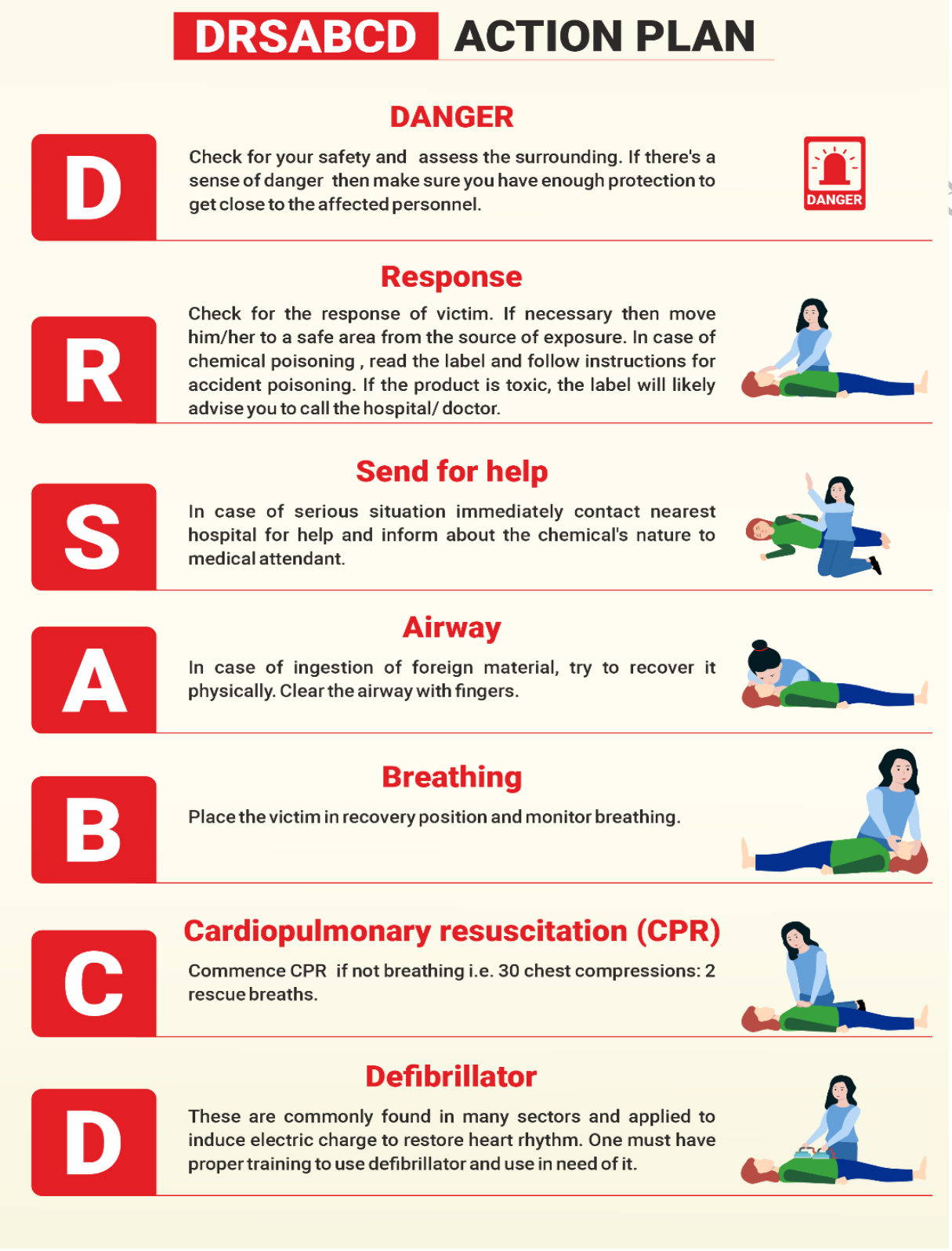

Fig. 29: The DRSABCD action plan for treating chemical poisoning

Treatment for simple chemical poisoning:

Skin and Eyes: If chemicals splash onto the skin, contaminated clothing, gloves, and lab coats should be removed immediately. Wash the affected skin area thoroughly with soap and water for at least 15 minutes, and flush with plenty of water to reduce the extent of injury. If symptoms persist, seek medical attention at the nearest hospital. In the case of eye exposure, rinse the eyes gently with plenty of water for at least 15 minutes, keeping the eyelids open. Quick and decisive action is crucial, as a delay of even a few seconds may significantly increase the injury. Consult an eye doctor immediately.

Inhalation: Exposure to chemicals through inhalation can lead to symptoms such as eye, nose, and throat irritation, coughing, difficulty breathing, dizziness, headache, confusion, and even collapse. In such cases, leave the area immediately and move to an open area with fresh air. Keep the patient as quiet as possible, and cover them with a blanket to prevent chilling. If breathing stops, use artificial respiration by mouth. Seek medical attention if symptoms persist.

Ingestion: If any chemical has been ingested accidentally a chemical, consult a doctor immediately. Vomiting should not be induced unless recommended by a medical professional. However, if an ingested chemical is not in the category of acid/ alkali and the sufferer is conscious, give them milk or water may be given to dilute the chemical.

Swallowed poison: If the poison has been swallowed, induce vomiting immediately. Mustard oil or table salt in a glass of warm water is good for this purpose. Touching the throat internally with a finger will also induce vomiting. The vomiting process should be continued till a clear liquid starts coming out of the stomach. If the patient goes into convulsions or an unconscious state, vomiting should be induced. If the poison is due to ingestion of mercury compounds, egg white and milk should be given first, and then vomiting should be induced. At the end of inducing vomiting, soothing substances like raw egg white (mixed with water), butter, or cream milk must be given.

Safety and Protective Equipment

Disposable masks: Wearing a mask in a hydroponic unit is essential to protect against inhaling harmful chemicals and dust from fertilizers, and pesticides. It reduces exposure to airborne allergens and pathogens, promoting a healthier environment. Masks also help prevent cross-contamination between plants, safeguarding their health.

First aid kits: keep a prepared first aid box with antiseptic lotion, bandages, scissors, tweezers, hand sanitizer, antibiotic ointment, burn cream, etc., at your workplace at all times.

Fig. 30: First Aid Kits

Rubber footwear: Wearing rubber footwear in the hydroponic unit is important for protecting against water spills and maintaining dryness. This can provide a level of insulation against electric shocks, especially in wet environments where the risk of electrical hazards is higher.

Personal protective clothes: Protective clothes should be worn while working with agrochemicals. They are made up of special material that prevents damage to the body.

Head protection: Head protection is crucial when working with agrochemicals and may come as a standalone garment or part of a combined coverall or face shield with a hood.

Eye and face protection: For eye and face protection, a shield covering the forehead and face should be worn to protect against accidental splashes of harmful agrochemicals during opening or pouring from containers. Non-fogging goggles resistant to chemicals should be worn when handling dusts or granules.

Fig. 31: Various personal protection equipment

Protective gloves: Hand gloves should be used during the handling of agrochemicals, as these chemicals may be absorbed through the skin or cause

damage to the skin. Generally, it should be at least 0.4 mm thick. The gloves of wrist length may be used for spraying toxic pesticides.

Emergency Response

Emergency response is a protective measure taken to control or alleviate the prompt side-effects of any kind of incident. It is one of the four-phase cycles in emergency management, which comprises mitigation, preparedness, response and recovery. Emergency responses help save lives and for the well-being of affected residents. The following are some key steps by which one can successfully handle the emergency situation-

- Train a task force for emergency response action for the workplace (for example, snakebite, fire, confined space entry, heat stress, or chemical spill).
- Keep the safety awareness level of workers high at all times.
- Maintain emergency response equipment.

Health and safety awareness in the workplace

- Encourage seniors to keep an eye on those working in the workplace.
- Use charts and visuals to demonstrate commitment to health and safety.
- Encourage safe work practices while discouraging unsafe work practices.
- Even at the cost of repetition, communicate that safety is of prime importance while at work.
- Those new to undertaking spray or pesticide application must be supervised or advised to report immediately about any adverse effects on the health of the operator.
- Respond and act promptly to all health and safety concerns.
- Set an example in the use of all preventive and protective materials and practices.
- Keep young trainees away from the operational area, or supervise them personally to ensure that they do not come close to equipment which they are not yet trained to use.

Practical Exercise

Activity 1

Identification of the Components of a First Aid Kit

Materials required:

Pen, pencil, notebook, First Aid Kit

Procedure:

1- Open the first aid kit and observe all the items inside.
2- Identify and list each component found in the kit.
3- Group the items into categories:
   - Bandages, gauze, adhesive tape.
   - Pain relievers, antiseptics, ointments.
   - Scissors, tweezers, thermometer.
   - CPR mask, first-aid manual, gloves.
4- For each item, note its purpose and how it should be used in an emergency.

Activity 2

Identification of Safety and Protective Devices

Materials Required:

Pen, pencil, notebook, gloves, goggles, masks, earplugs, reflective vests, fire extinguisher

Procedure

1- Identify the different types of protective devices used while handling and applying chemicals.
2- Understand their use through pictorial charts.
3- Identify and understand about each item and its uses.
4- Discuss about different types of chemical poisoning. What are the immediate symptoms?
5- Demonstrate the use of different protective devices.
6- Prepare chart showing different protective devices and their use.

Check Your Progress

Fill in the Blank

1. Poisoning is the lethal disruption of the body's physiological mechanism caused by toxic _____.
2. Protective gloves used during handling of agrochemicals should be at least _____ mm thick.
3. In case of chemical splashes on the skin, the affected area should be washed with soap and water for at least _____ minutes.
4. Head protection may come as a standalone garment or part of a combined coverall with a _____.

Multiple Choice Questions

1. Which of the following is a symptom of pesticide poisoning?
    a) Improved appetite
    b) Tremors
    c) Increased strength
    d) Rapid weight gain
2. What is the primary purpose of wearing rubber footwear in a hydroponic unit?
    a) Aesthetic appearance
    b) Protect against water spills and electric shocks
    c) Increase mobility
    d) Enhance chemical absorption
3. Which of the following materials is ideal for gloves used in handling agrochemicals?
    a) Cotton
    b) Plastic of 0.4 mm thickness
    c) Rubber of 0.4 mm thickness
    d) Silk
4. What should be done after vomiting induced by ingestion of poison?
    a) Give raw egg white, butter, or cream milk
    b) Leave the patient unattended
    c) Continue inducing vomiting indefinitely
    d) Administer a random chemical antidote
5. What is a key action in the emergency response process?
    a) Avoiding preparedness drills
    b) Encouraging unsafe practices
    c) Training a task force for emergency response
    d) Ignoring the safety equipment's maintenance

Subjective Questions

1. Why is the use of rubber footwear essential in a hydroponic unit?
2. Enlist safety guidelines to ensure a safe working environment.

Session 3: Safe Use of Agricultural machinery

Agricultural field operations today depend on various agricultural machinery, tools, and equipment. The use of machinery demands great care with all the necessary safeguards.

The accidents associated with agricultural machinery is caused due to the following reasons:

- Lack of adequate or proper training for operators.
- Poor maintenance of tools and machinery.
- Using a machine that is not suitable for the task at hand.
- Failure in following proper norms of a safe system of work.
- Missing or defective safety devices or machine guards, thus exposing the workers to accidents.
- Unsafe methods for clearing blockages on the premises.

Checking the tools and machinery before use-

Checking equipment and tools before the usage of them in hydroponics is important for maintaining device performance and preventing capability issues. The following is a checklist you may comply with to make sure everything is in suitable running order:

- Inspect intake and output lines of water pumps for blockages, ensure connections and seals are leak-free, and confirm the pump operates at the correct flow rate. Verify electrical connections and check for loose wires.
- Check air pump tubing for cracks or blockages, ensure adequate air supply for proper aeration, and listen for any unusual noises that may indicate wear or damage.
- Test bulbs or LEDs in the lighting system for flickering or dimming, verify timers and controllers are correctly programmed, and clean reflectors and surfaces to avoid blocking light.
- Ensure proper functioning of the nutrient reservoir and fertigation system components, including pressure gauges (2 to 6 bar), UV/Ozone disinfection units, filters (primary, secondary, and biological), PVC tanks, reciprocating pumps, and EC/pH/humidity measuring devices. Regularly calibrate sensors and check battery levels. Verify that control valves are working properly with the correct power supply.
- Inspect grow trays and channels for cracks or leaks, clean thoroughly, and ensure proper slope for gravity-fed systems.

- Flush pipes to check for blockages and confirm all connections are secure to prevent leaks.
- Regularly clean water and air filters in filtration systems, and replace old filters according to manufacturer recommendations.
- Check grow media (e.g., coco coir, perlite) for pests or mould, and replace it if contamination or microbial growth is observed.
- Verify settings for automated systems (e.g., lighting, watering, nutrient dosing) and ensure backup power systems are installed and functional.
- Ensure proper operation of environmental controls, including fans for air circulation, dehumidifiers for humidity control, and CO2 enrichment systems for correct operation and safety features.

1. Water Pumps

- Check for blockages by inspecting the intake and output lines for clogs. Ensure all connections and seals are intact and free of leaks. Confirm that the pump is operating at the correct flow rate to meet system requirements.
- Verify the electrical connections by checking the pump's connectivity and ensuring there are no loose wires.

2. Air Pumps and Air Stones

- Check the tubing: Check for cracks or blockages inside the air lines.
- Test air flow: Make sure that the air pump is supplying adequate aeration /air stones are functioning properly.
- Noise ranges: Pay attention to any uncommon noises indicating wear or damage.

3. Lighting System

- Check out lighting: Test the bulbs or LEDs for flickering or dimming.
- Test timers and controllers: Ensure your lights schedule is programmed correctly and is functioning satisfactorily.

4. Nutrient Reservoir/ Fertigation System

For cultivation in large areas, automated machineries are used. Proper functioning of each part of the nutrient system is necessary to deliver nutrients to the growing crops.

- **Pressure gauge-** It is used to measure the irrigation water. Optimum pressure for irrigation lies between 2 to 6 bar.
- **UV/Ozone disinfection unit-** If the nutrients are used without disinfecting, they can cause serious plant diseases. For this, we use a

disinfection unit. This UV unit consists of an in-line control switch, a central control module, a UVA sterilizer and a transformer unit.

- **Filters-** Filters are used to clear water and nutrient solution in a hydroponic farm. These filters can be categorised into primary, secondary and biological filters. They should be cleaned at regular intervals to prevent blockages.
- **PVC Tanks**- A hydroponic reservoir tank, or say PVC tank, is used to hold and circulate the hydroponic nutrient solution. Regular inspection and cleaning should be done to avoid any contamination.
- **Reciprocating pump-** It is used to deliver a precise amount of nutrient solution, especially where the delivery pressure required is high. It uses a piston and cylinder to move the fluid.
- EC, pH, humidity measuring devices-

  Calibrate sensors: Regularly calibrate to ensure correct readings.

  Check battery tiers: If your sensors probe of pH, EC, Humidity and TDS are battery-powered, fully charged or replaced.

- **Control valves-** Control valves are used to control the flow of nutrients supplied through the system. A solenoid coil is incorporated to actuate the valve. One should make sure that a proper input supply is there to actuate the coil before starting the fertigation system.

5. Grow Trays and Channels

- Look for cracks or leaks: Test trays and channels for structural integrity to prevent water leakage.
- **Clean thoroughly:** Grow Trays and Channels.
- Make certain proper slope: Make sure that channels are set at the best perspective for gravity-fed structures, if required.

6. Pipes and Tubing

- Check for blockages: Flush pipes to make sure there are no obstructions.
- Test connections: Make sure all pipes and tubes are connected properly to check for leakage.

7. Filtration systems

- Smooth filters: Whether or not its water or air filters, make sure they are clean and functioning properly.

- Update vintage filters: Swap out filters in the event that they display symptoms of damage or if it's time for replacement in step with the manufacturer's recommendation.

8. Grow Media:

- Look for pests or mould: Check media used (e.g., coco coir, perlite) for installation free from contamination.
- Update if essential: If the media is indicating signs and symptoms of contamination /growth of the microbes or infestation, replace it.

9. Automation system:

- Take a look at automation systems: If computerized structures for lighting, watering, or nutrient dosing are installed, ensure that each setting is functioning properly.
- Backup strength: Ensure backup electricity structures are installed (if relevant) and functioning.

10. Environmental Controls (enthusiasts, dehumidifiers, and so on.)

- Test fan operation: Make sure that everyone fanatics are working well for good enough air circulation.
- Check the functioning of it and maintain humidity properly as desired
- CO_2 systems: If using CO_2 enrichment, take a look at for correct operation and protection features.
- Ordinary inspection and protection of your hydroponic gadget can save your device from failure and help ensure a successful growing cycle.

Safety precautions to be taken during use of Agricultural Machinery

Agriculture has been the backbone of India for a long, long time. With the advancement in technology, the agriculture sector has boosted production along with efficiency. With the help of modern tools and machinery, the production has increased many times. With the advancement in technology, there is also a need for proper training to maximise the output and minimising the hazards. One must opt for the following guidelines/instructions while using agricultural machinery-

- Mitigate chemical exposure by reducing direct contact with chemicals.
- Ensure safety protocols are followed to prevent chemical exposure.
- Monitor regular electrical safety checks to prevent hazards like electric shocks or fires.

- Ensure that all wiring, joints, screws, and plugs are well-maintained and that electrical equipment is ergonomically installed.
- Implement emergency provisions to avoid potential hazards. Provide proper training to all personnel involved in harvesting activities, ensure availability of emergency kits, safety equipment, and clear signage
- Make sure entry and exit points are visible in case of an emergency.
- Ensure personnel engaged in activities have basic knowledge of the hydroponic setup. This helps them identify potential hazards and respond appropriately.
- Regular training sessions should be conducted to keep workers updated on new technologies.
- Proper maintenance and inspection of equipment, safety measures, and safety training ensure the safe operation of the hydroponic system and prevent accidents.
- Provide proper protective gear to personnel working with chemicals, machinery, and electrical systems to reduce the risk of injury.
- Foster a culture of safety awareness among all workers, emphasising the importance of following safety guidelines and procedures.
- By executing these safety measures, the risk of accidents is minimised, ensuring maximum production with reduced fatalities and risks.

Mitigating Chemical exposure-

While using equipment for chemical distribution among plants/crops, one must reduce exposure to plants; otherwise it can harm the beneficiary directly or indirectly.

❖ **Electrical Safety Checks-**
- Loose or short-circuited wiring results in a hazardous situation, such as electric shock, electric fire, etc.
- One must ensure that all the joints and screws- plugs are well maintained.
- Electrical equipment must also be checked ergonomically, to determine if they are properly installed or not.

❖ **Emergency Provisions-**
- Emergency measures are taken to avoid any hazard from occurring.

- Proper training must be provided to all personnel engaged in harvesting activities.
- All the emergency kits, like First Aid, safety equipment, and proper signs, must be there.
- Entry and exits must be clearly visible in case of any emergency situation.

Basic knowledge about a hydroponic setup up-

- Personnel engaged in labour activities must have some basic knowledge about set-up, so that they can easily point out the friendly or hazardous situation and act according to the situation.
- Regular training sessions must be held to aware the personnel about new technologies.

Thus, by executing these basic safety precautionary measures, one can ensure maximum production with minimum fatality. To ensure quality and quantity with reduced risk factors, we must opt for these principles and requirements.

Daily/Periodic Mandatory Inspections of Machinery

To obtain efficiency and enhanced life duration of machinery, along with minimising accidental occurrences, one must opt for Daily/Periodic maintenance of the above-mentioned equipment. Safety Checks, which must be covered on a Daily/Periodic basis, are listed as below-

1. Regular inspection for static as well as moving parts for any loose connection, wear-tear or any kind of leakage will mitigate any kind of catastrophe.
2. Regular examination of belts for any irregular wear and tear, any kind of improper alignment.
3. Regular inspection of the connection, whether it's mechanical or electrical. If any loose connectivity, then resolve it immediately.
4. Periodical inspection of starters and Miniature Circuit Breaker(MCB) for any foul sequencing will prevent the motor from any kind of damage.
5. Periodical inspection of hydraulic motors for any kind of damage will ensure smooth operation of the machinery.
6. Daily check of machinery for its basic function, such as lifting, dwelling, lighting, etc., will enable efficient performance.
7. Daily checks for any wear and tear in hydraulic pipes and leaks of fluid will prevent equipment from any kind of major accident.

Daily or periodic mandatory inspection for the use of machinery

- Check water levels, nutrient solution, and air pumps to ensure the system is functioning correctly and that the water/nutrient mix is balanced.
- Inspect tubing and irrigation lines for kinks, cracks, and general wear to prevent leaks or blockages in the hydroponic system.
- Once the system is running, check all pumps and valves, ensuring that they are operating smoothly and that the water flow is consistent for proper irrigation.
- Inspect any cracks or damage in the grow trays, PVC pipes, and structural components that may cause parts to break or malfunction unexpectedly.
- Maintain a safe distance from the hydroponic equipment during system setup, maintenance, and adjustments to avoid injury.
- Take caution if there are any overhead power lines, especially during equipment movement or maintenance tasks involving tall structures or lifting tools.
- Report any unsafe actions or system malfunctions to supervisors so that preventive measures can be implemented and the system can continue to run smoothly and safely.

Protective Measures During Operating Machinery-

1. When using any machine, first stop the engine until all machine elements are still.
2. Before operating any kind of equipment/machinery one must have thorough knowledge about the operating sequence and dimensions of the Machine.
3. During the operation of any machinery, one must know the emergency procedure to immediately bring the machinery to a halt, if required.
4. When operating the machine, one should not have any distracting elements like a mobile, earbuds or a radio with them. Otherwise, it can lead to an accident.
5. For moving parts of machinery, there is a constant need for inspecting the moving wires. If they are out of cradle, then the operator must stop the machine and look for maintenance support.
6. Before operating any machinery, the operator must go through the operator's manual for safety instructions and to operate the machinery efficiently.
7. A guard or shield shall be provided to minimise the possibility of damage contact during normal operation or servicing of tractors and implements.

8. The operator should be skilled enough to identify the error displayed on the machine and should be trained to rectify the same.
9. Danger and caution signs shall be used to warn against unsafe practices.
10. Last but not least, the operator must be equipped with safety gear while operating any kind of machinery.

Practical Exercises

Activity 1

Demonstrate general inspections for use of the machinery.

Materials required:

Different types of equipment, users guide, pen, and notebook.

Procedure:

1- Identify and select the machinery
2- Check the different parts of machinery
3- Identify the open moving parts or feeding parts which pose hazard
4- Check assembling of each part of the equipments
5- Demonstrate use of machinery after inspection.

Activity 2

Demonstration of Precautions Taken During Use of Agricultural Machinery

Materials required:

Different types of Safety equipment, pen, and notebook.

Procedure:

1. Observe the agricultural machinery and identify the safety hazards associated with its operation and note down following:
    - proper use of personal protective equipment
    - pre-operational checks before start any machinery.
    - Safe operating procedures
    - Post operational safety measures

Check Your Progress

Fill in the Blank

1. Missing or defective _____ expose workers to accidents while operating machinery.
2. Pressure gauges in fertigation systems should maintain an irrigation pressure between _____ bar.
3. Air pumps should be inspected for _____ and unusual noises to ensure proper aeration.

4. Grow trays and channels should be inspected for _____ to prevent water leakage.

Multiple Choice Questions

1. What is the primary reason for inspecting machinery before use?
   a) To reduce noise levels
   b) To ensure proper functioning and prevent accidents
   c) To increase the system's speed
   d) To clean the machinery
2. What is the ideal irrigation pressure range for a fertigation system?
   a) 1 to 2 bar
   b) 10 to 15 bar
   c) 5 to 10 bar
   d) 2 to 6 bar
3. Which component is used to measure water pressure in a hydroponic system?
   a) Pressure gauge
   b) Control valve
   c) Reciprocating pump
   d) EC meter
4. What is the primary function of control valves in a fertigation system?
   a) To measure pressure
   b) To control the flow of nutrients
   c) To calibrate EC meters
   d) To clean nutrient solutions
5. What is the purpose of using danger and caution signs during machinery operation?
   a) To improve visibility
   b) To enhance productivity
   c) To warn against unsafe practices
   d) To guide machinery assembly

Subjective Questions

1. What is the main cause of accidents in agricultural machinery?
2. Why is it important to inspect water pumps before use?
3. What should be checked regularly in grow media to ensure safe hydroponic farming?
4. What safety precaution should be followed before operating agricultural machinery?

Glossary

Acute Illness: Short-term adverse health effects caused by exposure to toxic substances. Symptoms typically appear quickly and resolve within a short period.

Adventitious Roots: Roots emerging from non-root tissues like stems or leaves, aiding in support and nutrient uptake.

Agrochemicals: Chemicals used in agriculture to enhance productivity, including fertilizers, pesticides, and herbicides.

Antidote: A substance that neutralizes or counteracts the effects of a poison.

Automation System: Technology-driven systems designed to automatically manage processes like irrigation, nutrient delivery, and climate control in agricultural setups.

Bioaccumulation: The build-up of substances, such as chemicals or toxins, in an organism over time, often through the food chain.

Calibrate: The process of adjusting and fine-tuning instruments to ensure precise and accurate measurements.

Chemical Poisoning: Adverse health effects resulting from exposure to chemicals via skin contact, inhalation, or ingestion.

Chronic Illness: Long-term health issues arising from repeated or prolonged exposure to toxic substances.

Cryogenic Cooling: A technique using extremely low temperatures, typically from liquid nitrogen or solid carbon dioxide, to quickly reduce the temperature of produce.

Decontamination: The process of removing hazardous substances from people, equipment, or surfaces to ensure safety.

Dehumidifier: A device used to extract excess moisture from the air, ensuring optimal storage conditions for crops.

Digital Agriculture Platforms: Online services providing tools and insights to enhance agricultural productivity, marketing, and logistics.

Digitalization in Agriculture: The adoption of digital tools and technologies to optimize agricultural processes, including precision farming and market access.

Endocrinal System: The system of glands responsible for hormone production, regulating metabolism, growth, and other vital body functions.

Evaporative Cooling: A natural cooling process where water evaporation lowers temperatures and increases humidity, suitable for perishable produce.

Farm Harvest Prices: The monetary value farmers receive for their crops at the conclusion of the harvest season.

Farmers' Producer Organizations (FPOs): Groups formed by farmers to collectively market their produce, negotiate prices, and access better resources.

Fertigation System: An integrated system that combines fertilization with irrigation, ensuring efficient nutrient and water delivery to plants.

Logistics: The efficient planning, management, and execution of transportation and delivery of goods within the supply chain.

Mandis: District-level wholesale markets where agricultural produce is traded.

Middlemen: Individuals or entities acting as intermediaries between farmers and end consumers or retailers.

Multicubes: Compact units consisting of multiple substrate cubes, used for growing seedlings uniformly.

Pelletized Seeds: Seeds coated with materials to improve handling, sowing, and germination efficiency.

Safety Awareness: The understanding and proactive recognition of risks and hazards to minimize accidents and injuries.

Subsidy: Financial assistance provided by the government to support farmers and encourage the adoption of specific agricultural practices.

Answer Keys

Unit 1: Management of Hydroponic crop

Session 1

Fill in the Blank

6- Short

7- 5.5; 5.8

8- True

9- 21, 26

10- 2.4; 3.5

Multiple Choice Questions

1-d, 2-b, 3-a, 4- a, 5-d

Session 2

Fill in the Blank

1. Oxygen
2. Contamination
3. mS/cm
4. tops

Multiple Choice Questions

1-c, 2-c, 3-d, 4- a, 5- c

Match the Following

1 - A, 2 - B, 3 - C, 4 - D, 5 - E

UNIT 2: Process of Carrying out Harvesting and Post-Harvest Management of Hydroponic Produce

Session 1

Fill in the Blank

1. Colour, size, aroma
2. pruning shears, sharp knife
3. contamination

4. petioles

Multiple Choice Questions

1-C, 2-D, 3-C, 4-B

Match the Following

1 – d, 2 – c, 3 – a, 4 – b, 5 - e

Session 2

Fill in the Blank

1. Precooling
2. Hydro
3. Trimming
4. Controlled Atmosphere Storage
5. Forced-air

Multiple Choice Questions

1-D, 2-B, 3- C, 4- A. 5-C

Match the Following

1 – a, 2 – b, 3 – c, 4 – d

UNIT 3: Basic Marketing Activities for Small Enterprise

Session 1

1. Primary
2. Fixed or stable
3. Vary
4. Marketing channels

Multiple Choice Questions

1. (a) 2. (a) 3. (b)

Session 2

Fill in the Blank

1. Price
2. Supply
3. 20%

4. Consumers

Multiple Choice Questions

1-c, 2-b, 3-c, 4-d, 5-a

UNIT 4: Hygiene, Cleanliness, Safety and Emergency Procedures

Session 1

Fill in the Blank

1. natural; synthetic
2. resistance
3. contamination

Multiple Choice Questions

1-b, 2-c, 3-b, 4-d, 5-a

Session 2

Fill in the Blank

1. chemicals
2. 0.4
3. 15
4. hood

Multiple Choice Questions

1-b, 2-b, 3-c, 4-a, 5-c

Session 3

Fill in the Blank

1. safety devices
2. 2 to 6
3. blockages
4. cracks or leaks

Multiple Choice Questions

1-b, 2-d, 3-a, 4-b, 5-c

List of Credits

DAAH, PSSCIVE, Bhopal

Fig 1

Fig 2

Fig 16

Fig 17

Fig 18

Fig 19

Fig 20

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Fig 22

Fig 23

Fig 24

Fig 25

Fig 26

Fig 27

Fig 28

Fig 29

Fig 30

Fig 31

Dr. Neelu Singh, Tropical Forest Research Institute, Jabalpur

Fig 3

Fig 4

Fig 5

Fig 6

Fig 7

Fig 8

Fig 9

Fig 10

Fig 11

Fig 12

Fig 13

Fig 14

Fig 15