Draft Study Material

Spice Crops Cultivator

(QUALIFICATION PACK: Ref. Id. AGR/Q0603)

SECTOR: AGRICULTURE

Grades 12

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NCERT

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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.

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Module 1
Weed Management in Spice Crops

Module Overview

To ensure food security to the ever-growing population, that is going to be more than 9 billion by 2050, it is now necessary to increase the global food production by 70 percent. The efforts are now made to meet the multiple challenges, which are majorly faced in agricultural activities due to climate change, and to minimize the economic losses that occur due to biotic and abiotic factors. Among various biotic stresses, weeds are considered as most notorious as they cause huge yield losses to agricultural crops. Weeds are known to cause direct yield losses by suppressing crops' growth and development, and competing with crops for space, sunlight, water and nutrients. Weeds harbour insect, pests and diseases causing pathogens which leads to huge economic losses. They also destroy native habitats of weedy and wild relatives of the crops posing as a serious threat to losses of biodiversity. A number of factors like rainfall pattern, weed emergence time, weed density, types of weeds and architecture of crop plants affects yield in all the crops.

Learning Outcomes

After completing this module, you will be able to:

- Identify common weed species affecting spice crops and understand their impact on crop yield and quality.
- Describe and apply various weed management techniques

Module Structure

- Session 1: Manage Weeds in Spice Crops
- Session 2: Integrated Weed Management in Spice Crops

Session 1: Manage Weeds in Spice Crops

Introduction

Any plant growing in the field, other than the main crop, is a weed. Weeds compete with the main crop for the nutrients, water, sunlight, and space which results into the reduction in its yield.

Jethro Tull (1731) was the first to use the term "weed" which means as a plant growing where it is not desired.

The primary objective of Integrated Weed Management (IWM) is to reduce weeds as they compete with the main crop for the nutrient, water, air and other resources. Designed in a planned sequence, IWM involves the combined utilization of mechanical, chemical and cultural practices of weed management without affecting the ecosystem. The nature and intensity of the species to be controlled, the sequence of crops that are raised in the rotation, the standard of crop husbandry, the readiness and timely availability of any method, and the economics of different weed management techniques are some of the potent considerations that determine the success for the exploitation of the Integrated Weed Management approach.

Characteristics of weeds

There are so many characteristics of weeds due to which they are found everywhere, even in adverse conditions. Some of these characteristics of weeds are as follows: -

S. No.	Characteristics	Examples
1.	Produce large number of seeds	*Striga juncea* produces 50 lakh seeds/plant; *Amaranthus viridis* produces 1.78 lakh seeds/plant
2.	Formation of special structure for effective dissemination	*Physallis minima* forms balloon structure
3.	Germinate in adverse condition	*Rumex spinosus* can germinate in acidic soil
4.	Dormancy habit	*Chenopodium album* can germinate after 20-25 years
5.	Faster growth	*Phyllanthus niruri* in cumin
6.	Ability to propagate vegetatively	*Cyperus rotundus* can propagate through tubers
7.	Deeper root system	*Convolvulus arvensis* roots can go upto 20 feet
8.	Long viability	*Cyperus rotundus* have 78 % viability

9.	Similarity of seeds with crop seeds	*Cichorium intybus* in berseem
10.	Resist control & eradication	Spines on *Solanum xanthocarpus*
11.	Competitiveness & aggressiveness in nature	*Chenopodium alba* in corriander

Critical period of crop weed competition

Critical period of crop weed competition can be defined as the shortage time span during the crop growth when weeding results in highest economic returns. The crop benefit obtained by weeding during this period is almost similar to that about by the full season weed free conditions.

The crop canopy in the early period of growth is inadequate to smother the weed growth. By early reproductive phase, the crop develops adequate leaf area to smother the weed growth. Hence, weed competition in crop field is invariably severe in early stages of crop growth than at later stages. Generally, in a crop of 100 days duration, the initial 20-35 days after sowing should be maintained weed free for obtaining highest yield. The critical period for crop-weed competition, on an average, is 30-40 days for most of the crops.

Harmful effects of weeds

There are so many harmful effects of weeds.

- Reduction of crop yield due to competition for
  - ✓ Moisture
  - ✓ Nutrients
  - ✓ Space
  - ✓ Solar energy or light
- Reduction in crop quality
- Reduction in land value
- Harbours insects & pests
- Blocking of irrigation channels
- Causes health problem in humans and animals

Table 1.1 Shows Health Problem Occur Due to Weeds in Humans

S. No.	Health problem	Weed responsible
1	Hay fever & Asthma	*Pollens of Ambrosia & Franseria*
2	Dermatitis (Skin allergy)	*Parthenium hysterophorus, Ambrosia artimissifolia*
3	Itching & Inflamation	*Utrica spp.; Muceena pruriens*
4	African sleeping sickness	Brush weed
5	Dropsy disease	*Argemone maxicana*
6	Malaria, Encephalitis	*Salvinia auriculata*

Importance of weeds

All the weeds are not always harmful in nature. When the weeds grow in the crop field, then only it is harmful as it competes with our main crop and reduces its yield. Otherwise, many weeds have important characteristics. Some of these are as follows: -

S.No.	Importance	Examples
1	Maintaining soil fertility	*Typha spp.* Adds 1-3 % nitrogen
2	Controlling soil erosion	*Cynodon dactylon; Evolvulus arvensis*
3	Used as fodder	*Cichorium intybus; Cynodon dactylon*
4	Have medicinal value	*Leucas aspera* is used in snake bite
		Striga spp. is used in diabetes
		Phyllanthus niruri is used in jaundice
		Argemone maxicana is used in skin diseases
5	Have economic value	*Cichorium intybus* is used in adding flavour to coffee

		Cyperus rotundusis used in making agarbatti
		Sachharum spontaneum is used in roof making
6	Maintains pH	*Argemone maxicana*is used for making alkaline soil acidic
		Rumex acetocella is used for making acidic soil alkaline
7	Used as ornamental plants	*Lantana camara; Eichhornia crassipes*
8	Used in cleaning water	*Eichhornia crassipes*
9	Adds organic matter to soil	*Amaranthus viridis; Convolvulus arvensis*
10	Used as vegetable	*Chenopodium alba*
11	Religious purpose	*Cynodon dactylon* (Doob)

Indicator plant: Some plants are sensitive to the deficiency of particular nutrient. Such plants which show deficiency symptoms of the nutrient earlier than the other plants are known as the indicator plants. Some weeds also act as an indicator plant, so they are grown in the crop fields in few numbers for the earlier detection of the nutrient deficiency.

Table 1.2 Showing Weeds as Indicator Plant

S.No.	Weed Name	Indicator metal
1.	*Crotolaria cobaltica*	Cobalt
2.	*Crotolaria florida*	Manganese
3.	*Commelina benghalensis; Acalypha indica*	Copper
4.	*Acacia spp.*	Iron
5.	*Salsola nitrata*	Boron

6.	*Echhornia crassipes*	Copper; Lead; Zinc
7.	*Artemisa spp.*	Gold; Cadmium; Uranium

Classification of weeds on different basis

1. **Based on cotyledon:** Based on the number of cotyledons, weeds can be classified as monocots and dicots.
   a) **Monocot weeds:** The stem is hollow and round, internodes are short and hard, and the leaves are slender, long and have parallel veins. Most of the grasses belong to this group, For example, *Cyperus rotundus, Cynodon dactylon,* etc.
   b) **Dicot weeds**: It has taproot system with broad leaves. Veins on leaves are netted and these produce flowers. For example, *Chenopodium album; Mellilotus alba,* etc.
2. **Based on life cycle:** Based on life cycle the weeds are classified as Annual, Biennial and Perennial weeds.
   a) **Annual weeds:** Weeds that live only for a season or a year and complete their life cycle in that season or year are called as annual weeds. For example, *Amaranthus viridis; Cleome viscosa.*
   b) **Biennial weeds:** They complete the vegetative growth in the first season, flower and set seeds in the succeeding season and then dies. For example, *Cichorium intybus; Circium vulgare.*
   c) **Perennial weeds:** They complete life cycle in more than two years. For example, *Convolvulus arvensis*; *Lantana camara.*
3. **Based on season:** Based on season, the weeds are classified as Rabi, Kharif, Summar and Multi season weeds.
   a) **Rabi season:** For example, *Phalaris minor; Avenafatua*
   b) **Kharif season:** For example, *Echinochloa colona; Ludwigia parviflora*
   c) **Summar season:** For example, *Tephrosia purpurea*
   d) **Multi season:** For example, *Phyllanthus niruri*
4. **Based on growth habbit:**
   a) **Erect:** For example, *Chenopodium album*
   b) **Prostrate:** For example, *Monogyna spp.*

c) **Creeping:** For example, *Cynodon dactylon*

d) **Climbing:** For example, *Cepholendra indica*

5. **Based on nature of stem:** On the basis of the development of bark tissues on their stems and branches, weeds are classified as woody, semi-woody and herbaceous species.

   a) **Woody weeds:** Weeds include shrubs and under shrubs and are collectively called brush weeds e.g., *Lantana camara; Acacia arabica*

   b) **Semi-woody weeds:** e.g., *Pluchea lanceolata*

   c) **Herbaceous weeds:** Weeds have green, succulent stems and are of most common occurrence around us e.g., *Amaranthus viridis*

6. **Based on morphological characteristics:** Based on the morphology of the plant, the weeds are also classified in to three categories:

   a) **Grasses:** All the weeds which come under the family Poaceae are called as grasses which are characteristically having long narrow spiny leaves e.g., *Chloris barbata; Digitaria sanguinalis*

   b) **Sedges:** The weeds belonging to the family Cyperaceae come under this group. The leaves are mostly from the base having modified stem with or without tubers e.g., *Cyperus rotundus; Fimbristylis miliacea*

   c) **Broad leaved weeds:** This is the major group of weeds. All dicotyledon weeds are broad leaved weeds e.g., *Eclipta alba; Leucas aspera*

7. **Based on origin:** Based on origin, the weeds are also classified in to two categories.

   a) **Indigenous:** e.g., *Phalaris minor; Cichorium intybus*

   b) **Exotic or alien:** e.g., *Argemone maxicana*; *Parthenium hyterophorus*

8. **Based on crop weed association:** Based on crop weed association, the weeds are also classified in to three categories.

   a) **Total root parasitic:** The weeds which are totally dependent on the roots of the host plant are known as total root parasite e.g., *Orobanche spp.*

   b) **Total stem parasitic:** The weeds which are totally dependent on the stem of the host plant are known as total stem parasite. e.g., *Cuscutta reflexa*

   c) **Partial root parasitic:** The weeds which have chlorophyll and therefore, synthesize their organic food themselves but they fulfill their mineral and water requirements from their host plants and attack their roots. e.g., *Striga lutea*

Table: List of Common Weeds

S. No	Botanical Name	English Name	Local Name	Family
1.	*Anagallis arvensis* L.	Scarlet pimpernel	Krishnaneel	Primulaceae
2.	*Argemone mexicana* L.	Prickly poppy	Satyanashi	Papaveraceae
3.	*Dactyloctenium indicum*	Button grass	Makdaghaas	Poaceae
4.	*Commelina benghalensis* L.	Benghal dayflower	Kenna	Commelinaceae
5.	*Gomphrina celosides*	Bacheolar's button	Gumma	Amaranthaceae
6.	*Achyranthes aspera* L.	Devil's horsewhip	Chirchita/ Latjira	Amaranthacea
7.	*Solanum nigrum* L.	black nightshade	Makoi	Solanaceae
8.	*Euphorbia hirta* L.	Asthma weed	Choti dudhi	Euphorbiaceae
9.	*Mellilotus alba* Medikus	White mellilot	Peelisenji	Fabaceae
10.	*Portulaca oleraceae* L.	Green purslane	Lunia	Portulacaceae
11.	*Cyperus rotundus*	Nut grass	Motha	Cyperaceae
12.	*Cynodon dactylon*	Bermuda grass	Doob	Poaceae
13.	*Phyllanthus niruri* L.	Grip weed	Hazardana	Euphorbiaceae
14.	*Digera arvensis*	False amaranth	Lahsua	Amaranthaeceae
15.	*Physallis minima* L.	Sunberry	Rabhari/ Chirpoti	Solanaceae
16.	*Cleome viscosa* L.	Asian spiderflower	Hulhul	Capparaceae
17.	*Amaranthus virdis* L.	Calalu	Choulai	Amaranthaceae
18.	*Alternanthera sessilis* L.	dwarf copperleaf	Ganduri/ guru	Boraginaceae
19.	*Tridax procumbence* L.	Coatbuttons, Mexican daisy	Kaali rukhadi	Asteraceae

20.	*Trianthema portulacastrum* L.	Black pig weed	Satha	Aizoaceae

d) Partial stem parasite: The weeds which have chlorophyll and therefore, synthesize their organic food themselves but they fulfill their mineral and water requirements from their host plants and attack their stem. e.g., *Loranthus spp.*

Fig.1.1: Anagallis arvensis

Fig.1.2: Argemone mexicana

Fig.1.3: Dactyloctenium indicum

Fig.1.4: Commelina benghalensis

Fig.1.5: Gomphrina celosides

Fig.1.6: Achyranthes aspera

Fig.1.7: Solanum nigrum

Fig.1.8: Euphorbia hirta

Fig.1.9: Mellilotus alba Medikus

Fig.1.10: Portulaca oleraceae

Fig.1.11: Cyperus rotundus

Fig.1.12: Cynodon dactylon

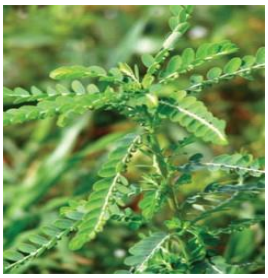


Fig.1.13: Phyllanthus niruri

Fig.1.14: Digera arvensis

Fig.1.15: Physallis minima

Fig.1.16: Cleome viscosa

Fig.1.17: Amaranthus virdis

Fig.1.18: Alternanthera sessilis

Fig.1.19: Tridax procumbence

Fig.1.20: Trianthema portulacastrum

Activities

Visit a nearby spice growing field

Materials required: Herbarium file, Blotting paper, Notebook, Pen, Pencil, Tape, etc.

Procedure:

- Visit a nearby field.
- Observe the weeds growing in the field.
- Collect at least 10 weed species.
- Dry and press the specimen in the blotting paper.
- Paste the dried and pressed weed on the herbarium sheet.
- Write down the following information:
  - (i) Botanical Name of weed
  - (ii) Local name of weed
  - (iii) Family

(iv) Place of collection

(v) Date of collection

(vi) Name of the crop where weed collect

Check Your Progress

A. Fill in the blanks

1. The term “weed” was first used by .....
2. Botanical name of motha is .....
3. ..... is a biennial weed.
4. Solanum nigrum belongs to the family .....
5. Total root parasitic weed is .....

B. Multiple Choice Questions

1. The critical period for crop-weed competition on an average is...

a) 70-80 days

b) 30-40 days

c) 5-10 days

d) 20-25 days

2. Example of weed that can be used as ornamental plant...

a) *Chenopodium alba*

b) *Amaranthus viridis*

c) *Lantana camara*

d) *Cyperus rotundus*

3. Crotolaria florida is an indicator weed which metal...

a) Copper

b) Cobalt

c) Iron

d) Manganese

4. *Cyperus rotundus* belong to family of...

a) Poaceae

b) Euphorbiaceae

c) Cyperaceae

d) Asteraceae

C. Match the Columns

A	B
1. Rabi season	a. *Tephrosia purpurea*
2. Kharif season	b. *Echinochloa colona*
3. Summer season	c. *Phalaris minor*
4. Multi season	d. *Phyllanthus niruri*

D. Subjective Questions

1. Define weed. Write down the characteristics of weed.
2. Classify the weeds on the basis of lifecycle with example.
3. Discuss the importance of weeds.

Session 2: Integrated Weed Management in Spice Crops

An Integrated Weed Management may be defined as the combination of two or more weed-control methods, at low input levels, to reduce weed competition in a given cropping system below the economical threshold level. Weeds can be managed by following methods: -

1. Cultural or Agronomical or Manual Method
2. Mechanical Method
3. Biological Method
4. Chemical Method

1. Cultural or agronomical or manual method

- **Use of competitive crops & cultivars:** Crops, which are more competitive in nature, in their earlier stage have less weeds in comparison to other crops. Example: - Green gram, black gram, cowpea, etc., spread very fast in its earlier stage, leaving less space for weeds to grow as compared to pearl millet or sorghum. This results into fewer weeds in them as compared to pearl millet or sorghum. Weed infestation is lesser in more competitive cultivars as compared to less competitive cultivars. Example: - Spreading

varieties of groundnut have less weeds as compared to bunch type varieties.

- **Crop rotation:** Growing different crops on same piece of land is known as crop rotation. Example: - Orobranchial in mustard can be managed by doing crop rotation.
- **Inter-cropping:** Growing of two crops on same piece of land during same season in definite row pattern is known as Inter-cropping. This gives less space to the weeds to grow in the crop field.
- **Use of cover crops or live mulches or smother crops:** Covers crops or smother crops, like green gram, cowpea, etc., have restrict weed infestation.
- **Method of fertilization:** If the fertilizer is applied either through band placement or through row placement, weed infestation is lesser as compared to the broadcasting method of fertilizer application.
- **Stale seed bed:** It is one of method to manage weeds. In this method, field is irrigated, and weeds are allowed to grow for two weeks. After that the weeds grown in the field are ploughed down and then the crop is sown.
- **Summer ploughing:** Field is ploughed deeply during summers so that the underground parts of weed plants are exposed to the sunlight which leads to its desiccation.
- **Use of closer planting density:** Row-to-Row distance is reduced in the crop field which gives lesser space to the weeds to grow.
- **Use of higher seed rate of crop:** Higher seed rate results into higher plant population of the crop. As a result, more crop plants grow in the field in comparison to the weeds. Crop plants dominate and suppresses the growth of the weeds.
- **Method of planting:** Less weeds are found in the transplanted rice field as compared to the direct seeded rice.
- **Irrigation method:** Field irrigated with drip system have less weeds in comparison to the field in which irrigation is given through sprinkler or furrow method.
- **Soil solarization:** Soil solarization is an eco-friendly method that is compatible with organic and integrated crop management systems. It is efficient in controlling soil-borne pathogens and weeds with a long-term effect on an agro-ecosystem, regarding soil nutrient improvement and microbial activities.

- **Flooding:** This is the common practice used for weed management in the transplanted rice. In this method, seed germination and root respiration of the already germinated weeds are hindered by creating anaerobic condition.

2. Mechanical method

- **Hand weeding:** This is the most common and traditional method of weed management. Weeds are removed with the help of sharp-edged sickle or *Khurpi.* Due to increasing labour cost and scarcity of labour, it becomes the costly method of weed management.
- **Hoeing:** It is a post-planting intercultural operation done in line sown crops for weed management with the help of hand hoe, wheel hand hoe or hand weeder, cono weeder, power weeder, etc.
- **Land levelling:** Field is levelled before sowing of the crop which results into uniform germination of crop and weeds both. Weeds can be controlled more easily in these place as compared to the weeds grows in scattered manner.
- **Digging:** It is done for the patch or spot control of the obnoxious or perennial weed.
- **Sickling or Chopping:** In this method, top part of the weed is removed to prevent seed production and underground plant part left, especially in drainage or irrigation channel, to starved resulting into the death of the plant.
- **Mowing and Slashing:** This is mainly used in non-cropped areas like roadside, parks, bunds, canals, pastures, lawns, etc. It is done with the help of tractor, battery or electricity operated mowers or choppers.
- **Dredging:** In this method, aquatic weeds are mechanically pulled out from the water bodies with their roots and rhizomes.
- **Chaining:** This method is also used for controlling aquatic weeds with the help of long and heavy chain which is attached to the tractor or animal. Weeds are pulled or rubbed over the bottom and embankments of the ditches. The fragmented weeds are collected by the hooks or nets.
- **Use of Rotovator:** Rotovator is the tractor operated instrument used for weed management in the crop field.

Fig.1.21: **Wheel Hand Hoe**

Fig.1.22: **Rotovator**

3. Biological method

- **Insects:** *Octotoma scabripemis* and *Uroplata* giraldi controls *Lantana camara, Zygogramma* controls *Parthenium hysterophorus, and Alternanthera philoxiroides* is controlled by flea beetle.
- **Snails:** Coontail & algae is controlled by *Marsia species*.
- **Bio herbicides:** Bio herbicides are the artificially cultured pathogens which are made available in the sprayable formulations. Examples include De Vine, Collego, Bipolaris (Controls Jhonson grass), Biolophos (Non-specific).

4. Chemical method

Types of herbicides: -

1. **Selective herbicides** – Herbicides which kills only weeds and not the crops, due to their selectivity, are known as Selective herbicides. They are crop specific. For example, 2,4-D in Wheat crop, Atrazin in Pearlmillet crop.
2. **Non-selective herbicides –** Herbicides which kills all the herbs irrespective of crops and weeds are known as non-selective herbicies. They are not crop specific. For example, Diquat; Paraquat

Application time of herbicide application: -

1. **Pre-Plant incorporatio (PPI) –** They are applied *before* a crop is planted, mainly at the time of land preparation. Often require incorporation into soil. For example, Fluchloralin
2. **Pre-emergence application (PE)** – They are applied within 48 hours of sowing of crops. For example, Pendimethalin, Atrazin, etc.
3. **Post-emergence application (PoE)** – They are applied directly to foliage after weed emergence. Generally, they are applied 20-25 days after sowing on the standing crop. For example, 2,4-D, Imazethapyr, Quizalofop, Propaquizafop, etc.

Integrated Weed Management Practiced in Some Important Spices are as Follows: -

S.N.	Crop	Weed Management	
		Hand weeding or Hoeing (DAS)	**Chemical Method**
1.	Coriander	40-45 & 60-65 DAS*	Pendimethalin @1.0 kg a.i./ha or Oxyflurofen @0.15 kg a.i./ha as Pre-Emergence
2.	Cumin	30-35 & 50-60	Pendimethalin @1.0 kg a.i./ha or Oxyflurofen @0.05 kg a.i./ha or Oxadiargyl @0.05 kg a.i./ha as Pre-Emergence

3.	Fennel	8-10 cm height	Pendimethalin @1.0 kg a.i./ha as Pre-Emergence
4.	Fenugreek	30-35 & 50-60	Pendimethalin @0.750 kg a.i./ha or Oxyflurofen @0.15 kg a.i./ha as Pre-Emergence

*DAS = Days After Sowing

Precautions for herbicidal weed control

1. Always use flat fan nozzle
2. Never repeat spray
3. Spray under sufficient moisture condition
4. Use right dose for spray
5. Apply sufficient quantity of organic matter in next crop to minimize residual effect.
6. Follow rotation of herbicide if possible.
7. Read the herbicide label carefully and follow the direction on the label.
8. Check the sprayer before starting spray. It should be working properly.
9. Clean the spray with clean water before and after spraying.
10. Calculate the amount of commercial product required for area to be sprayed.
11. Mix the herbicide in small quantity (1-2 litres) or water first and make the required volume with water (6500-600 litres/ha).
12. Divide the field to be sprayed into parts of 200 sq. m. each and spray 12-15 litres of herbicide solution in each part. This will ensure uniform spray in whole area.
13. Do not spray herbicide on windy and rainy days.
14. Judge the stage of crop and weeds in case of post-emergence application.
15. Store the herbicide in labelled containers and way from food material and children.

Calculation of commercial product of the herbicide

Quantity of commercial product required =

$$\frac{\textbf{\textit{Rate of Herbicide application (a.i.)Kg/ha}}}{\%\ \textbf{\textit{active ingredient}}} \times 100$$

***a.i. = active ingredient**

Example: Rate of Atrazine (active ingredient) application per ha = 1.25 kg/ha

Active ingredient in commercial product = 50 WP

Thus, the quantity of commercial product of atrazine per hectare

$$= \frac{\textbf{\textit{Rate of Herbicide application (a.i.)Kg/ha}}}{\%\ \textbf{\textit{active ingredient}}} \times 100$$

$$= \frac{1.25}{50} \times 100$$

= 2.50 kg/hectare

Activities

Activity I: Visit a dealer or distributor of herbicide. Collect information of five herbicides and complete following observation table: -

S.N.	Name of the herbicide	Commercial name of the herbicide	Recommended for the crops	Dose of the herbicide

Activity II: Calculate the quantity of commercial product of pendimethalin 30 % EC required for spraying in 2500 m2, if the dose of pendimethalin is 750 gms a.i./ha.

(Hint: 1 hectare = 10,000 m2)

Check Your Progress

A. Fill in the blanks

1. In..... method of irrigation, there will be less infestation of weeds.

2. ……beetle is used to the management of *Parthenium hysterophorus*.
3. ……is a most common and traditional method of weed management.
4. ……is a mechanical method used for management of aquatic weeds.
5. Herbicides which kill the all herbs irrespective of crops and weed known as……

B. Multiple Choice Questions

1. Herbicides which are applied after weed emergence are called
   a) Pre-emergence herbicide
   b) Post-emergence herbicide
   c) Pre-planting herbicide
   d) None of the above
2. Example of selective herbicides _____
   a) 2,4-D
   b) Diquat
   c) Paraquat
   d) None of these
3. Growing of two crops on the same piece of land during same season in definite row pattern known as
   a) Crop rotation
   b) Inter-cropping
   c) Mixed-cropping
   d) Mono-cropping
4. Field is covered with 25-50 µ transparent polythene sheet during summer is called
   a) Soil solarization
   b) Summer ploughing
   c) Flooding
   d) All of the above

C. Subjective questions

1. Discuss some agronomical methods of weed management.
2. What do you understand by mechanical method of weed management? Enlist five mechanical methods of weed management.
3. Define herbicide. Classify herbicide on the basis of selectivity.
4. Describe in detail Integrated Weed Management. Discuss the integrated weed management practiced in Coriander, Fennel, Cumin and Fenugreek.

Module 2
Integrated Pest and Disease Management in Spice Crops

Module Overview

Spice crops are more susceptible to different types of pests like insects, nematodes and mites. In India, up to 50–80% yield loss of spice crops incurs due to various diseases. The crop loss caused by diseases, such as wilt, root rot, blight, powdery mildew, downy mildew etc. Root rot complex, caused by Fusarium species, is most severe during early growth stage resulting in up to 35 per cent yield loss. The use of fungicides and insecticides in spices, to control diseases and insect-pests, is increasing because of intensive farming practices and expanding cultivation into new areas and in seasons beyond the traditional range of crops. Pesticides are synthetic compounds which are hazardous for the environment and also for beneficial insects. Indiscriminate use and improper application of pesticides has created an ecological imbalance due to the destruction of beneficial insects and the emergence of pesticide resistant species and strains. The increasing use of pesticides is a major factor for the rising cases of pesticide residue in spice. In the past, a single approach to control pests and diseases was in practice, which was neither economical nor safe. Therefore, a systematic approach of Integrated Pest or Disease Management (IPM or IDM) was adopted.

Learning Outcomes

After completing this module, you will be able to:

- Identify the major insect-pests that affect spice crops,
- Demonstrate effective pest management techniques, implement integrated pest management (IPM) strategies to sustainably control insect-pests in spice crops

Module Structure

- Session1: Identify Major Insect-Pests of Spice Crops and their Management
- Session 2: Identify Major Diseases of Spice Crops and their Management

Session1: Identify Major Insect-Pests of Spice Crops and their Management

What is insect-pests?

A thorough knowledge of morphology, nature of damage, vulnerable stage of pest, damaging stage, pre-disposing factors, susceptible stages of host, natural enemies and predators help in preventing and controlling them effectively. All insects belong to the class Insecta. Their body is segmented and mostly comprises three main segments, i.e., head, thorax and abdomen. Insects have two pair of wings and three pairs of legs. According to structure of wing (pteron), they are classified into different orders, such as Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera and Orthoptera, etc. All these insects belonging to different orders may have different life cycles with different damaging stages and nature of damage. With a view to accomplish a better pest management, all these factors are important, but the most important is how (nature of damage) and when (damaging stage) they attack the host.

Integrated pest management

Improper and uncontrolled use of chemical pesticides in agriculture has resulted in a number of harmful adverse effects, such as ecological imbalances, environmental pollution, pesticide residues in food, soil, and water, pest resurgence, dangers to human and animal health, destruction of bio-control agents, development of pest resistance, etc. Because of this, Government of India, in year 1985, has adopted Integrated Pest Management (IPM) as cardinal principle and main plank of plant protection in their overall Crop Production Programme. Integrated Pest Management (IPM) is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop specific (cultural) management strategies and practices to grow healthy crops and minimize the use and risks posed by pesticides to human health and the environment for sustainable pest management.

Insect pest management

Anything that interferes with the life of insect pests and makes them difficult to survive in the field or on plants either by killing them or through repelling so that their population is reduced is known as Insect Pest Control. Various methods as shown below are employed for their control-

Cultural methods: Cultural methods of pest control consist of regular farm operations in such a way that it either destroy the pests or prevent them from causing economic loss.

Various cultural methods/practices useful for pest control are as follows:

- Preparation of nurseries or main fields free from pest infestation by removing plant debris, trimming of bunds, treating of soil and deep summer ploughing which kills various stages of pests.
- Testing of soil for nutrients deficiencies on the basis of which fertilizers should be applied.
- Selection of clean and certified seeds and treating seeds with fungicide or bio pesticides before sowing for seed borne disease control.
- Selection of seeds of relatively pest resistant/tolerant varieties which play a significant role in pest suppression.
- Proper drainage system in field should be adopted.
- Proper water management (alternate wetting and drying to avoid water stagnation) as the high moisture in soil for prolonged period is conducive for development of pests especially soil borne diseases.
- Proper weed management is well-known fact that most of weeds besides competing with crop for micronutrients also harbour many pests.
- Growing trap crops on the borders or peripheries of fields. There are certain crops which are preferred more by a pest species are known as trap crops for that pest. By growing such crops on the border of the fields, pest population develop there which can be either killed by using pesticides or its natural enemies are allowed to develop there for natural control.

Physical methods

These methods are mostly useful in controlling pests in a closed environment, like storage or greenhouse or pot plant. This includes moderation in temperature, radiation and altering humidity of the structure. Drier conditions are unfavourable for pests. Similarly, low temperature of storage inhibits infestation. UV and γ-rays also prove lethal for pests.

Mechanical methods

- Whenever possible, remove and destroy egg masses, larvae, pupae and adults of insect pests and diseases parts of plants.
- Use of light traps and destruction of trapped insects.

- Fixing of bird perchers in the field for allowing birds to sit and feed on insects and their immature stages viz., eggs, larvae and pupae.
- Phototropic insects, such as borers (buds, pods and fruits), are attracted to light during night. Light source with a trap of kerosene or some pesticide solution will trap such insects and provide effective control.
- Use of pheromone traps for monitoring and suppression of pest population.
- Use of sticky bands for white ants and other tiny insects stick on the bands and die there without moving anywhere afterwards. Different colours attract insects differently, so coloured papers are pasted on a card board and sticky material is spread over it. Yellow colour attracts white flies and aphids while blue colour attracts to thrips.

Biological control methods: Biological control of insect pests through biological means is most important component of IPM. In broader sense, bio-control is use of living organisms to control unwanted living organisms (pests). In other words, deliberate use of parasitoids, predators and pathogens to maintain pest population at level blow those causing economic loss either by introducing a new bio-agent into the environment of pest or by increasing effectiveness of those already present in the field.

- **Parasitoids:** These are the organisms which lay eggs in or on the bodies of their hosts and complete their life cycles on host bodies as a result of which hosts die. A parasitoid may be of different type depending on the host developmental stage in or on which it completes its life cycle. For example, egg, larval, pupal, adult, egg-larval and larval pupal parasitoids come from different species of Trichogramma, Apanteles, Bracon, Chelonus, Brachemeria, Pseudogonotopus etc.
- **Predators:** These are free living organisms which prey upon other organisms for their food. Examples are different species of spiders, dragon flies, damsel flies, lady bird beetles, *Chrysopa species*, birds etc.
- **Pathogens:** These are micro-organisms which infest and cause diseases in their hosts as a result of which hosts die. Major groups of pathogens are fungi, viruses and bacteria. Some nematodes also cause diseases in some insect pests. Important examples of fungi are different species of *Hirsutella, Beauveria*, Nomurae and Metarhizium which have been reported to infest and kill large number of insects (up to 90%) in the fields. Among viruses, most important examples are of Nuclear Polyhedrosis Virus (NPV) and granulosis viruses. Outbreak of viruses in armyworms, cut worms, leaf folders, hairy caterpillars and plant hoppers have been reported many times. Among

bacteria, *Bacillus thuringiensis* (B.t.) and *B. popillae* are very common examples.

- **Botanical insecticides:** These are naturally occurring chemical substances (insect toxins) extracted or derived from plants. They are also called natural insecticides. Neem contains many active compounds like azadirachtin, which acts as feeding deterrents. It is effective on several types of insects, mites and nematodes. Neem oil (2-5 per cent) is found effective and neem cake (250 kg/ha) helps control fruit and shoot borer.

Nicotine is derived from tobacco and is used to control insects, such as aphids and mites in greenhouses

Chemical method

Use of chemicals to kill or repel insect pests comes under this method.

- **Dust:** Dry formulation with inert carrier. Available concentrations are from 1–10%. For example, Quinolphos 4 D, etc.
- **Wettable powder (WP) and dispersible powder (DP):** Dry formulation but can be applied with water. For example, Sulphar 80% w.p.
- **Coated granules (CG):** Dry formulation, but particle size is more than found in powder. Applied in soil. For example, Carbofuran 3% C.G.
- **Emulsifible concentrates (EC):** Liquid formulation with emulsifiable agents, which form emulsion in water. Use for aerosol or foliar spray. Most of the insecticides are available in this formulation, e.g., Cypermethrin 5EC, Malathion 50EC, etc.
- **Suspension concentrates (SC):** Formulation consist of having as active ingredient dispersed in water have grown in popularity due the e.g., Monocrotophos 36 SC, etc.
- **Fumigants:** They are found in liquid or solid form, e.g., methyl bromide, Aluminium Phosphide, but these fumigants act in a gaseous state and are used in stored grain.

Major insect-pest of spice crops

Shoot borer (*Conogethes punctiferalis*): The shoot borer (*Conogethes punctiferalis*) is the most serious insect pest of ginger and turmeric. The larvae bore into pseudostems and feed on internal tissues resulting in yellowing and drying of leaves of infested pseudostems. The presence of a bore-hole on the pseudostem through which frass is extruded and the withered and yellow central shoot is a characteristic symptom of pest infestation. This adult pest is a medium

sized moth with a wingspan of about 20 mm with the wings having orange-yellow colour with minute black spots. Fully-grown larvae are light brown with sparse hairs. The pest population is higher in the field during September-October.

Management:

- Deep summer ploughing during summer with soil solarisation.
- For the management of shoot borer, destroy the infested shoots
- Place light traps @ 1 /acre for the management of shoot borer and operate it between 6 PM and 10 PM to attract and trap them. Destroy the collected moths.
- Release of *Trichogramma chilonis* @ 40,000/acre for shoot borer.
- Spray Lamda-cyhalothrin (0.0125%) or Malathion (0.1%) at intervals of 21 days from July to October. Start spraying as soon as the innermost leaf displays the first signs of a pest infestation.
- Apply neem oil (0.5%) at 15 days' intervals.

Rhizome scale (*Aspidiella hartii*): The rhizome scale (*Aspidiella hartii*), a major pest of turmeric and ginger, infests rhizomes in the field (at later stages) and in storage. Adult (female) scales are circular (about 1 mm diameter) and light brown to grey and appear as encrustations on the rhizomes. They feed on sap and when the rhizomes are severely infested, they become shrivelled and desiccated affecting its germination.

Management:

- Rhizome scale can be controlled by harvesting rhizomes at the right time, removing seriously contaminated rhizomes.
- Deep summer ploughing and soil solarisation reduces the insect pests.
- Select insect pest free rhizomes from scale infestation
- If the infestation persists, treat the seed material with quinalphos (0.075%), for 20–30 minutes, both before storing and before sowing.
- Apply well rotten sheep manure @ 10 t/ ha in two splits or poultry manure in 2 splits followed by drenching dimethoate 30 % EC @ 2 ml.

Aphid (*Aphis gossypii* and *Hyadaphis coriandri*): The most common insect that attacks the Cumin, Coriander, Fennel, Dill and Fenugreek crop is aphid are found in colonies sometimes very serious in patches on tender leaves, stem and inflorescence. Both nymphs and adults suck sap from the tender leaves thus

reducing market value. The severe infestation affects the yield and quality of leaves badly.

Management:

- Timely sowing, field sanitation, crop rotation and rouging is required.
- Sorghum/Maize/Bajra may be used as a barrier crop around cumin.
- Destruction of alternate host plants.
- Conservation of natural enemies and use of predators and parasitoids should be preferred.
- Apply fish oil rosin soap or Neem Seed Kernel Extract (NSKE) (3%), Neem oil (2%) or Tobacco decoction (0.05%).
- Use of yellow sticky traps for whitefly and aphids and blue sticky trap for thrips @ 8-10 traps/acre are observed effective.
- Use of bio-pesticide like NSKE 5% is suitable method of pest management.
- However, in case of severe infestation, consider need based use of chemical insecticides i.e., Emamectin benzoate @ 10 g ai/ha or Thiacloprid @ 0.24% to prevent losses.

Thrips (*Thrips tabaci*): Thrips are tiny insects. It is major pest of coriander cumin and fennel crops. Amongst the species of thrips attacking seed spices, Thrips tabaci is the major specie found on most of the seed spice crops. Both nymphs and adults' feeds on umbel, leaf sheath and stems of plants. Both nymphs and adults congregate in between the leaf sheath and stems of plants which results in drying of the leaves. Severe infestation results in drying of flowers and production of shrivelled fruits.

Management:

- Use botanicals Neem seed kernel extract (NSKE) 5.0%, Neem oil 2.0%, Azadirachtin 10000ppm @2.0ml/litre and bio-pesticides like *Verticillium lacanii* 1x108 CFU's/gm 5.0 g. /litre of water as foliar spray on the crops.
- There is no level claim of any insecticides in coriander crop. However, in case of severe infestation need based use of chemical insecticides i.e., Emamectin benzoate @ 10 g ai/ha or Thiacloprid @ 0.24% or Dimethoate 30EC @ 0.03% to prevent losses.
- Avoid spraying same chemical repeatedly. Stop foliar spray of chemicals before 10 days of flowering.

- Trips can be controlled by blue polyethene coated with a sticky material like castor oil or grease (20-25polyethene/ha) at equal distance.

Whitefly (*Bemisia tabaci*): The whitefly is serious insect-pest of coriander and cardamom. The adult is a soft-bodied, moth-like fly. The wings are covered with powdery wax and the body is light yellow in colour. The wings are held over the body like a tent. The adult males are slightly smaller in size than the females. Adults live from one to three weeks timespan. Nymphs and adults both feed on the lower surface of the leaves by sucking cell sap. The affected parts of the plant show yellowing and wrinkling of leaves. It also transmits leaf curl viral disease.

Management:

- Remove weed hosts, which harbour the white flies to reduce the incidence of whiteflies and associated viral diseases.
- Use resistant /tolerant varieties is a common practice.
- Treat seeds with Imidacloprid 70 WS @ 2.5 g per kilogram to provide protection for 25–30 days.
- Parasitic activity should be increased for natural balance of life.
- Collection and destruction of insect infested plant parts.
- Application of Cypermethrin-10EC-@ 1ml/L and Imidacloprid-17.8SL-@ 0.3 ml/L

Cinnamon butterfly (*Chilasa clytia*): This is the most serious cinnamon pest, especially in younger plantations and nursery, and is generally seen during the post monsoon period. The larvae of the cinnamon butterfly feed on tender and half mature leaves. In case of severe infestation, entire plant is defoliated and only midribs are left.

Management:

- Pest can be kept under check by collecting the butterflies with the help of net and destroying them.
- Insect can be controlled by spraying quinalphos 0.05 % on the foliage.

Leaf miner (*Conopomorha civica*): Leaf miner infests tender leaves of cinnamon plants in the nursery and field and is more serious during the monsoon season. The larvae of leaf miner feed on the tender tissues between the upper and lower epidermis of the leaf resulting in the formation of linear mines that end in blister-like patches. Severely infested leaves become crinkled and

malformed and later the mined areas dry up leading to the formation of large irregular holes on the leaves.

Management:

- Spraying Neem Seed Kernel Extract (NSKE) @ 4.0 per cent along with sticker is effective. This pest can be controlled by spraying the crop with Cartap hydrochloride 50% SP @ 1g/litre.
- These natural enemies, particularly larval and pupal parasitoids, are active between the months of July-August.
- These parasitoids can be used to control leaf miner insect.
- Insect can be controlled by spraying quinalphos 0.05 % on the foliage.

Stem borer (*Sahyadrassus malabaricus*): The stem borer major pest of clove. These are infesting the main stem of young trees at the basal region. The larva of the pest girdles the stem and bores downward into it. The girdled portion and bore-hole are covered with a mat like frass material. The infested trees wilt and succumb to the pest attack.

Management:

- The base of clove trees is to be inspected regularly for symptoms of pest infestation.
- In case the pest infestation is noticed on the stem, the mat-like frass has to be removed and then spray and inject quinalphos 0.1% around and into the bore hole.
- Swabbing the basal region of the main stem of young clove trees with carbaryl paste and keeping the basins of clove trees free of weeds are prophylactic measures for preventing the pest infestation.

Scale insects: Different types of scale insects such as black scales (*Saissetia nigra*) and white scales (*Pseudaulacaspis cockerelli*) are major pest of clove and nutmeg. The scales clustered together on the lower surface of leaves especially in nursery seedlings. The pest infestation results in yellow streaks and spots on affected leaves and in case of severe infestations the leaves wilt.

Management:

- Removal and of affected leaves and branches
- Spraying of dimethoate (0.05%) is recommended for the management of scale insects.

Pollu beetle (*Lanka ramakrishnai*): Pollu beetle are most serious pest for black pepper. The tender leaves and spikes are fed by the adult. The grubs eat the interior tissues of fruits by boring into them. Spikes and berries that have been infested become black and rot. When crushed, the damaged berries crumble.

Management:

- Spray Quinalphos (0.05%) twice between June - July and September - October.
- Spray Neemgold (0.6%) (an insecticide based on neem) in August, September, and October.
- Following the crop rotation, growing of insect tolerant varieties and using trap crops is applicable
- Deep ploughing, timely sowing and proper weeding is required.

Cardamom thrips (*Sciothrips cardamomi*): Nature of damage of this insect is in the form of laceration. The adults and larvae feeds on leaves, shoots, inflorescences and capsules. When the panicles are infested, flowers and immature capsules shed. A corky look caused by infestation on immature capsules lowers their market value.

Management:

- Grow resistant/tolerant varieties.
- Deep ploughing, timely sowing and proper weeding/ cleaning of field.
- Planting of alternate host should be avoided.
- Mulching with green leaves and other organic materials during summer months to conserves beneficial microflora.
- Use light trap @ 1/acre and operate between 6 pm to 10 pm.
- Install pheromone traps @ 4-5/acre for monitoring adult moths' activity and management.
- Spraying of neem oil @ 3 ml/litre water with soap solution is effective.
- During the months of March, April, May, August, and September, spray pesticides such quinalphos (0.025%).

Activities

Identify the major insect pests of spices crops.

Material required: Insect net, Collection box, Notebook, Pen, Pencil etc.

Procedure:

1. Visit a nearby farmer's field and note down the following information.
   - Crops grow in the field.
   - Stage and age of the crop.
2. Collect insect pests from the crops.
3. Identify the Insect-Pest.
4. Write control measures of the collected Insect-Pest.

Check Your Progress

A. Fill in the Blanks

1. All insect belongs the class .....
2. Phototrophic insects such as borers or attracted to light during .....
3. Yellow colour sticky band attracts .....
4. The shoot borer (*Conogethes punctiferalis*) in the most serious pest of ..... and .....
5. Sorghum/maize/bajra may be used as a ..... crop around cumin crops against aphid insect.
6. Insect body comprises three main regiments i.e., ..., ..., and .....

B. Multiple Choice Questions

1. How much quantity of neem oil is found effective ...

   (a) 15-20%

   (b) 2-5%

   (c) 10-15%

   (d) 5-10%

2. Thrips (*Thrips tabaci*) in the major pest of...

   (a) Coriander

   (b) Cumin

(c) Fennel

(d) All of the above

3. Which type of disease transmitted by whitefly?

(a) Bacterial disease

(b) Fungal disease

(c) Viral disease

(d) Nematode drains

4. The shoot borer population is higher in the field during _____.

(a) June-July

(b) March-April

(c) Sep-Oct

(d) Dec-Jan

C. Match the Following

A	B
1. Dust	a. Sulphur
2. Coated Granules	b. Quinalphos
3. Suspension Concentrates	c. Methyl bromide
4. Fumigants	d. Carbofuran
5. Wettable powder	e. Monocrotophos

D. Subjective Questions

1. What is Insect-Pests?
2. Describe the Integrated Pest Management?
3. Discuss about the biological control method of Insect-Pests?
4. Write about the following Insect-Pest and their management.
   - Aphid
   - Thrips
   - White fly
   - Stem borer

Session 2: Identify Major Diseases of Spice Crops and their Management

What is a disease?

A successful interaction between virulent pathogen and susceptible host in favourable conditions is called disease. Diseases are caused by fungi, bacteria and viruses. These disease-causing organisms are called pathogens. Pathogens may be soil-borne, carried through seeds or disperse through wind and water. Some viral diseases are transmitted by insect vectors.

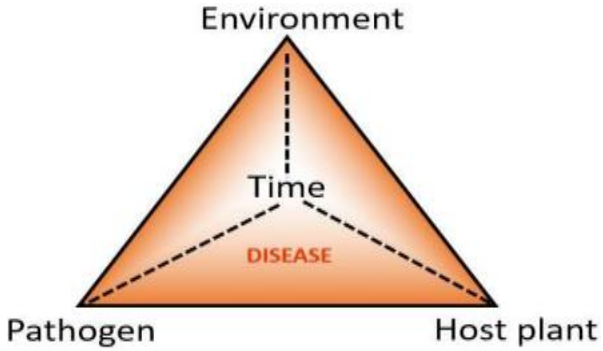


Fig: Disease Triangle

The interactions of the three components such as host, environment (physical viz., climatic, soil and topographical and biotic) and pathogen of disease have been visualized as a triangle generally referred to as the “Disease Triangle”.

Integrated disease management (IDM)

It is the integration of the methods used for avoiding and controlling diseases. IDM is defined as a decision-based process, including all possible control measures for optimising the control of pathogen and to keep the pathogenic population under control or below the level of economic loss.

Cultural method

Tillage: Soil-borne fungi, bacteria and nematodes, which serve as sources of infection, perpetuate in the soil. When the soil is ploughed, they get exposed to high temperature of the Sun. This reduces their population or activity within the soil.

Field sanitation: Plant pathogen (i.e. fungi, bacteria, and virus) survives on previous crop residues and weeds in the field, which serve as a major source of inoculums. Clean cultivation means removal of crop residues and keeping the bunds clean so that the pest population is minimised in the field. Plant disease

can be controlled by regular destroying of the diseased plant or weeds, which disrupt the disease cycle, and thus, prove as an effective source of control.

Crop rotation: The availability of susceptible hosts in every season or consecutive years increases the survival and persistence of diseases. Crop rotation with different crops or families breaks their persistence. Starvation of pests due to unavailability of susceptible hosts for long time makes it difficult for pests to survive.

Resistant varieties: Resistant varieties of spice crops have provided one of the most successful approaches to control plant pathogens of many crops, especially those which cannot be controlled by any other means. Some cultivators are resistant to a particular disease and are inherently less damaged than other genetically related plants growing in the same area.

Alteration in sowing time: Manipulation of sowing time and selection of early or late varieties also dodge pathogens. Certain diseases, like early blight, late blight, etc., are time-bound and require particular stage of growth of the plant to infect. Unavailability of susceptible stage fails to infect.

Seed treatment: Most of the seed and soil-borne diseases, such as damping-off, wilt, rots, dieback, anthracnose, etc., attack the crop through seeds or soil. Seed treatment reduces the chances of infection.

Crop density: High density of crop favours incidence of many diseases. Infections can move easily from a diseased to a healthy plant in a dense field. It is, therefore, desirable to plant the crop at required spacing.

Mechanical methods

It includes uprooting or pruning off diseased plants or parts so that infected material may not be able to transmit pathogens to healthy ones. Training and staking the crop facilitates plants in such a way that their leaves may not come in contact with the soil, and thus, infection or infestation is controlled. Erecting nets, sticky bands and mechanical traps control insect-vectors that may transmit viruses.

Bio-control of plant diseases

This is the most common method adopted nowadays as a biological control against many soil-borne diseases. Fungi like *Trichoderma herzianum* and *T. viride* and *Bacterium bacillus subtilis* have antagonistic properties against many fungi causing wilt and rot. Extracts of some plants are also well-known for their fungicidal properties. These are being used since a long time as pesticides. The extracts may be applied directly on soil or as a seed treatment or as sprays.

Chemical control

Use of fungicides

Fungicide is the chemical or combination of chemicals that are lethal to fungi and forces to escape the host before infecting them. Fungicides, according to their movement in the plant system, are of two types — First is Systemic fungicides, which on application on plants gets dissolved in the cell sap and its affectivity translocate to the whole system of plant irrespective of the place of application, such as Benlate, Calixin, Carbendazim (Bavistin), Demosan, Ridomil, Sten 50, Thiobendazol, Tilt, etc.; and Second is Contact fungicides, whose action on plants is restricted to the area of application, such as sulphur, mancozeb, Zineb, Rovral, etc.

Fungicide application

Soil drenching: In case of soil-borne infection due to fungi (like wilt, damping off, root rot) or nematodes (like root-knot), fungicide or nematicide should be applied to the soil. For example, fungicides like carbendazim, formaldehyde, etc. are used for this purpose.

Seed treatment: To avoid infection from the soil and from the seed, the easiest way is seed treatment. Generally, seeds are treated at the rate of 2.0–2.5 gms fungicide/kg of seed. Seed dressing drum or earthen pitcher can be used for treating the seeds. For example, fungicides like Carbandazim, Carboxin, etc. are used for this purpose.

Pasting to affected parts: In case of scorching Sun or in gummosis, the affected parts, such as stem, are pasted with Bordeaux paste @ 10%.

Foliar application: Aerial parts affected by foliar diseases can be controlled through foliar sprays of fungicidal formulations. Specialised sprayers are available for treatment. Generally, fungicides are sprayed with compatible insecticides, so it reduces the cost of application. These fungicides are sulphur, copper oxicloride, Maneb, Zineb, Nabam, etc.

Dip method: In this method, seedlings and cuttings are dipped before planting in the fungicidal solution for certain period to avoid infection. For example, Benlate, Captafol, Carbendazim, Maneb, Sulphur, Zineb, etc.

Common disease of spice crops

Damping off: This is a common disease among nursery plants, like fennel, nutmeg etc., that are generally attacked by the soil borne fungi. Fungi like Phytophthora and Pythium sp. are the causal organisms. Fungi infect seedlings in the collar region causing decay of tissues. Infected seedling cannot stand

upright and collapse. It is commonly seen during the rainy season and under water stagnation conditions.

Management:

- During the rainy season, the seedlings should be grown on a raised bed.
- Soil solarisation and sterilization may reduce the soil borne inoculum of fungi.
- Soil drench with mancozeb or carbendazim (2-3g/ litre of water) also reduces infection.
- Treat the seed with trichoderma 5g/kg seed.

Powdery mildew: This disease caused by *Erysiphe polygony* (crop loss up to 15-20%). It is a major disease in Coriander, Fennel, Fenugreek, and many other crops. In this disease, the white powdery growth is earlier seen on the both upper and lower surface of the leaves and later on it is seen on stem, petiole and on umbel. Favourable condition results in severe spread and infestation of disease by which quality and quantity of the crop reduces drastically.

Management:

- Use certified seed of resistant varieties.
- Collect and destroy infected plant debris.
- Avoid excess use of fertilizer.
- Sprinkling of water may help reduce powdery mildew.
- Remove and destroy plant debris and weeds.
- *Bacterium bacillus subtilis* helps in preventing the powdery mildew from infecting the plant.
- Spraying with soluble Sulphur or Kerathane @ 0.2% should be done after the interval of 10-15 days for 3 times.
- Spraying with Carbandazim @ 0.2% should be done 2-3 times to get rid from disease.

Leaf blotch: Leaf blotch is caused by *Taphrina maculans* this is major disease of turmeric. The initial symptom appears as small, oval, rectangular or irregular brown spots on either side of the leaves which soon become dirty yellow or dark brown. The leaves also turn yellow. In severe cases the plants present a scorched appearance and the rhizome yield is reduced.

Management:

- Spray mancozeb 0.2% or copper oxychloride 0.25% or propiconazole 0.1%, twice at fortnightly intervals.
- Foliar spraying of combination fungicide, Azoxystrobin 18.2% + Difenoconazole 11.4% SC (1 ml litre of water) first at the initiation stage of the disease followed by two sprays at 15 days' interval is recommended.

Leaf spot: It is a fungal disease caused by *Colletotrichum capsici* commonly seen in ginger, clove, turmeric and cinnamon etc. The disease appears as brown spots of various sizes on the upper surface of the young leaves. The spots are irregular in shape and white or grey in the centre. Later, two or more spots may coalesce and form an irregular patch covering almost the whole leaf. The affected leaves eventually dry up.

Management:

- Healthy planting material should be used.
- Cultural practices such as selection of well drained soils for planting is important for managing the disease as stagnation of water predisposes the plant to infection.
- Application of Trichoderma harzianum along with Neem cake @ 1kg/bed helps in preventing the disease.
- Once the disease is located in the field, removal of affected clumps and drenching the affected and surrounding beds with Mancozeb 0.2% checks the spread of the disease.
- Follow at least 2year crop rotation in infested areas.

Rhizome rot: The disease is caused by the fungus *Pythium aphanidermatum* is a serious disease in turmeric. The disease starts at the collar region of the pseudo stem and progresses upwards as well as downwards. The collar region of the affected pseudo stem becomes water soaked and the rotting spreads to the rhizome resulting in soft rot. At a later stage, root infection is also noticed. Foliar symptoms appear as light yellowing of the tips of lower leaves which gradually spreads to the leaf blades. In early stages of the disease, the middle portion of the leaves remain green while the margins become yellow. Later, the yellowing spreads to all leaves of the plant from the lower region upwards and is followed by drooping, withering and drying of pseudo stems. Collar region of the pseudo stem becomes soft and water soaked, resulting in collapse of the plant and decay of rhizomes. Rhizome rot affected plants will be seen as circular patches inside

healthy fields. The disease is soil-borne and rhizomes borne and occurs with the onset of monsoon.

Management:

- Follow crop rotation.
- Use disease free rhizome material for planting.
- Provide good drainage facility.
- Rhizome treatment with mancozeb (0.3%) or Copper Oxychloride (COC) 0.25% for 30 minutes before planting.
- When the disease is noticed in the field, the beds should be drenched with COC (0.25%) or Metalaxyl - mancozeb (0.125%).

Wilt: This disease is caused by *Fusarium oxysporum*. Initial infection occurs on roots and symptoms appear as lesions. Rotten tissue dies before coming above the soil surface. During post emergence mortality, lesions develop on hypocotyls. Initial symptoms are yellowing and curling of leaves. Affected plants show stunted growth and bear less fruit and flower. The roots of affected plants show vascular discolorations. This is disease common seen in Black Pepper and Clove crops.

Management:

- Solarization of soil during summer.
- Collect and burn infected crop residue.
- Deep ploughing should be done during summer season.
- Sowing disease-free seed to minimize the spreading of infection.
- Use oil cake for reduction of disease.
- Sowing of resistant varieties.
- Apply systemic fungicide such as carbendazim @ 0.2%.
- Seed treatment with Trichoderma viridae @ 4g/kg seed is also effective in reducing wilt incidence in coriander

Stem gall: The stem gall disease is caused by *Protomyces macrosporus*. It is another most serious disease in coriander crops. The symptoms appear as tumour like swelling on all parts of plant. In early stages, galls are soft and later it becomes hard and woody. Flower and fruit are hypertrophied. Clamydospores start depositing when moisture content is more along with high and low temperature respectively at day and night clubbed with fog at morning. The

result is in the formation of knots on the outer side of the stem and then slowly-slowly it spreads on leaves and fruits. This disease is more seen on late sowing crops and results in 15-25% loss of crop yield.

Management:

- Follow long crop rotation more than 3 years.
- Collect and burn infected crop residue.
- Deep ploughing should be done during summer season.
- Sowing of disease-free seeds.
- Early sowing of crop should be done in month of October.
- Use resistant varieties.
- Before sowing, treat the seeds with hexaconazole or propiconazole @ 0.1%
- Spraying of systemic fungicide Carboxin or Carbendazim @ 0.1% should be done four times for the prevention of this disease.

Alternaria blight: Cumin blight is the most important disease caused by *Alternaria burnsii*. Blight of cumin is the most damaging disease. Blight appears in the form of dark brown spots on leaves as well as stems, where by the stem tips bend downwards. Severely affected plants become blighted and do not bear seeds. Alternaria has been reported to be seed-borne and a cause of seedling blight in India. Cloudy weather at flowering stage increases the incidence of the disease in cumin.

Management:

- Only prophylactic measures are recommended for effective prevention against blight.
- Early sowing of cumin crop gets high intensity of disease and produces the unmarketable seeds.
- Bio-agents were found most effective for the mycelium growth of *A. burnsii* under in-vitro conditions.
- Turmeric rhizome, garlic clove and ginger rhizome extracts proved to be the best sources of plant origin for the reduction of radial growth and spore germination inhibition of blight pathogen.
- Systemic fungicides, hexaconazole and tebuconazole and non-systemic fungicide, mancozeb proved to be most effective against cumin blight.
- Use Dithane M-45 (0.2%) for the effective control of blight disease.

Anthracnose: It is a fungal disease caused by Colletotrichum capsici. This fungus is seed borne that also disperse through wind. It starts from tender twigs from the top of the plant causing necrosis and withering. Drying starts from top to bottom, hence it is called die back. Small, irregular, sunken, light brown lesions can be seen on leaves, shoots and fruits.

Management:

- Treat the seed with carbendazim @ 2.5 gm/kg seed.
- Remove and burn diseased parts of the plant.
- Foliar spray of Chlorothanonil 25 EC @1.5 gram/ litre water is found effective for control of the disease.
- Pre-planting treatment of two/ three node cuttings by immersing in a solution of carbendazim + mancozeb (0.1%) for 30 minutes and spraying Bordeaux mixture (1%) alternating with carbendazim (0.1%) is effective against the disease.

Leaf spot and die back: Leaf spot and die back disease is caused by Colletotrichum gloeosporioides. Small deep brown specks appear on the leaf lamina, which later coalesce to form irregular patches. In some cases, the affected portions are shed leaving shot holes on the leaves. Later, the entire lamina is affected and the infection spreads to the stem causing die back. Pruning the affected branches and spraying Bordeaux mixture 1% are recommended to control the disease.

Management:

- Collect and destroy the infected plant debris.
- With the initiation of the disease, spray the crop with Bordeaux mixture or copper oxychloride (0.3%) or combination of mancozeb (0.25%) and carbendazim (0.1%) and repeat at 14 days interval.

Bacterial wilt: Bacterial wilt, caused by Ralstonia solanacearum Biovar-3, is a soil and seed borne disease that occurs during south west monsoon. Water-soaked spots appear at the collar region of the pseudo stem and progresses upwards and downwards. The first conspicuous symptom is mild drooping and curling of leaf margins of the lower leaves which spread upwards. In the advanced stage, the plants exhibit severe yellowing and wilting symptoms. The vascular tissues of the affected pseudo stems show dark streaks. The affected pseudo stem and rhizome, when pressed gently, extrude milky ooze from the vascular strands. Ultimately rhizomes rot and emits a foul smell.

Management:

- The cultural practices adopted for managing soft rot are also to be adopted for bacterial wilt.
- The seed rhizomes may be treated with Streptocycline 50-100 ppm for 30 minutes and shade dried before planting.
- Once the disease is noticed in the field all beds should be drenched with Bordeaux mixture 1% or Copper oxychloride 0.2%.
- Seed rhizomes must be taken from disease free fields for planting.
- It is not advisable to plant ginger consecutively in the same field every year.
- Fields used for growing potato or other solanaceous crops are to be avoided.

Soft rot: Soft rot is the most destructive disease of ginger which results in total loss of affected clumps. The disease is soil-borne and is caused by Pythium spp. among which, P. aphanidermatum and P. myriotylum are widely distributed in the country. The fungus multiplies with build-up of soil moisture with the onset of Southwest monsoon. Younger sprouts are most susceptible to the pathogen. The infection starts at the collar region of the pseudo stem and progresses upwards as well as downwards. The collar region of the affected pseudo stem becomes water-soaked and the rotting spreads to the rhizome resulting in soft rot with characteristic foul smell. At a later stages, root infection is also noticed. Foliar symptoms appear as light yellowing of the leaf margins of lower leaves which gradually spreads to the leaf lamina. In early stages of the disease, the middle portion of the leaves remain green while the margins become yellow. The yellowing spreads to all leaves of the plant from the lower region upwards and is followed by drooping, withering and drying of pseudo stems.

Management:

- Since the disease is seed borne in nature, thus seed rhizomes are to be selected from disease free gardens.
- Treatment of seed rhizomes with mancozeb 0.3% or metalaxyl mancozeb 0.125% for 30 minutes before storage.
- The soil may be solarized before planting by covering the moist soil with a transparent polythene film for 45-50 days. Application of Trichoderma harzianum along with neem cake @ 1 kg/bed helps in reducing the incidence of the disease.
- Once the disease is located in the field, removal of affected clumps and drenching the affected and surrounding beds with mancozeb 0.3% or

metalaxyl mancozeb 0.125% or copper oxychloride 0.2% checks the spread of the disease.

Activities

Identify diseased samples of Spice crops.

Material required: Diseased samples of different spice crops, notebook, Pen, Pencil, etc.

Procedure: Observe the symptoms of diseased samples and write the following information.

1. Name of the crop
2. Name of the disease
3. Causal organism
4. Control Measures

Check Your Progress

A. Fill in the Blanks

1. A successful interaction between virulent Pathogen and Susceptible host in favourable condition is called…….
2. The seed and soil borne disease such as …… and ……..etc.
3. Combination of Chemicals found lethal to fungi and escapes the host from infection is called ……
4. Seeds are treated at the rate of ……. gm fungicide kg of seed.
5. Led blotch is caused by……. this is major disease of turmeric.

B. Multiple Choice Questions

1. Viral diseases are transmitted by …….
   (a) Wind
   (b) Water
   (c) Insect
   (d) None of the above
2. Disease occurs only when there is a ……..
   (a) Virulent Pathogen
   (b) Susceptible host

(c) Favourable Climate

(d) All of the above

3. ……. is a contact fungicides.

(a) Carbendazim

(b) Ridomil

(c) Mancozeb

(d) Sten 50

C. Subjective Question

1. Describe different cultural method of disease control.
2. Describe fungicides and their types.
3. Describe different method of fungicidal application.
4. Write about the following disease and their management.
   - Damping off
   - Stem Gall

Module 3
Herbal and Oil Yielding Spice Crops Cultivation

Module Overview

Spices are used in food and beverages to enhance its flavour, colour and aroma, and also as a preservative to increase their shelf-life. Spices may be derived from many parts of the plant: fruits, bark, flowers, leaves, rhizomes, roots, seeds, stigmas and styles or the entire plant tops. Whereas 'herb' is used as a subset of spice and refers to plants with aromatic leaves.

Essential oils are liquid products of steam or water distillation of plant parts (leaves, stems, bark, seeds, fruits, roots and plant exudates). An essential oil may contain up to several hundred chemical compounds and this complex mixture of compounds gives the oil its characteristic fragrance and flavour. An essential oil may also be fractioned and sold as an individual natural component.

Learning Outcomes

After completing this module, you will be able to:

- Understand the specific cultivation requirements for herbal and oil-yielding spices.
- Demonstrate best practices in planting, nurturing, and harvesting techniques and implement sustainable farming practices to enhance the quality and economic value of spices.

Module Structure

- Session 1: Cultivate Herbal Spices
- Session 2: Cultivating Oil Yielding Spices

Session 1: Cultivate Herbal Spices

Rosemary

Rosemery belongs to the family of 'Labiatae' Scientific name of Rosemary is "*Salvia rosmarinus*". it was formerly placed in the genus Rosmarinus as Rosmarinus officinalis. Rosemary is a perennial evergreen shrubby herb of 60 to 75 cm in height with a unique aromatic odour and a camphoraceous undertone. The dorsal side of the leaf is green and rough whereas it is white hairy on ventral side. The erect stems are divided into numerous long, slender branches that have ash-coloured scaly bark. Calyx and corolla of the flower are two-lipped. There

are two violets stamens and a long style. The plant flowers profuse and set seeds. The fruit is oval 4- sectioned Cremo carp.

Fig. 3.1: Rosemery Flowes

Fig. 3.2: Rosemery plants

Parts used

Stems, leaves and flowers are used as spices. The oil of rosemary that is extracted exclusively from the stem and leaves is superior to the oil that is extracted from the blooming tops, as instructed in the British Pharmacopoeia. Nearly all the commercial oil is distilled from the stem and leaves of the plant before it is in flower, which then smells more of camphor.

Vernacular names

Its vernacular names are – in Hindi: Rusmari, Bengali: Rosemary, Sanskrit: Rusmari

Origin and Distribution

Rosemary is the native of Mediterranean region where it grows wild along the sea coast. Rosemary is cultivated on large scale in Europe and California in US. It is also grown in Algeria, China, Middle East, Morocco, Russia, Romania, Serbia, Tunisia, Turkey, and to a limited extent in India. Temperate climate is suitable for the cultivation of Rosemary. Rosemary is cultivated on a limited area in Nilgiris in India. Central Institute of Medicinal & Aromatic Plants (CIMAP) introduced rosemary cultivation at its Bengaluru field station in late eighties and regular cultivation started from 1990 onwards.

Uses

Rosemary has wide range of uses in cosmetics, perfumery, culinary purposes, food processing etc. Fresh tender tops are used for garnishing and flavouring cold drinks, pickles, soups etc. Dried and powdered leaves are used as condiments. It bears therapeutic properties as carminative, anti-depressant,

anti-spasmodic, anti-microbial, anti-inflammatory, carcinogen blocker, liver-detoxifier and anti-rheumatic.

Varieties

Indian varieties

- ***Ooty-1:*** The leaves are dark green, thick and is willing to skin. The green and dry leaves is ideal for cooking imparts good flavour. The crop is ready to first harvest after 215 days of planting seedlings, however subsequent harvesting could be done at the intervals of three to four months in a year, hence it can be harvested three times in one year. Average green leaf yield of this variety is 13 tons per year. However, potential yield of this variety is 46 per cent higher than the local irakattaik. The variety is resistant against the leaf blight, the white fly and aphid.

International varieties

Upright-growing types of rosemary

These small shrubs can reach up to 1.5 m. Here are some of the best upright rosemary varieties are as-

- **Salvia rosmarinus:** The traditional common species of rosemary found in garden centres can grow vigorously up to 1.2 m tall with dense green foliage, light blue flowers, and a strong aroma.
- **Albiflorus:** Rosemary cultivar growing up to 1.0 m in height and wide canopy. It shows beautiful white flowers and short, dark green foliage.
- **Blue tuscan:** It has vividly blue flowers, large tender foliage, reaching a height up to 1.5 m, hence this variety makes a wonderful specimen in the garden. It is also excellent for use in the kitchen.
- **Gorizia:** Growing up to 1.5 m tall, this makes an excellent shrub in your garden. It bears very pale violet-blue flowers and dark green foliage.
- **Heavenly blue:** It is a very compact type, only reaching up to 0.5 m tall. This variety is perfect for borders in your garden or for growing in a pot. It bears pale blue flowers and lovely green foliage.
- **Miss Jessopp's Upright:** With light blue flowers and a strong aroma, Miss Jessopp's Upright rosemary is a delight in the garden. It can grow very tall and sturdy into a well-shaped shrub with dense foliage.
- **Rex:** A very robust variety that can grow up to 1.2 m tall. Its foliage is dark green, and its flowers are dark blue.

- **Roseus:** This upright rosemary has lovely pink-coloured blossoms that contrast nicely with its green foliage. It can grow into a small shrub up to 1 m tall. It has excellent aromatic foliage for use in the kitchen.
- **Salem:** The variety makes an excellent hedge and can grow up to 1.2 m tall. It has dark green foliage with pale, but striking blue flowers. This variety needs protection from hard freezes as it is only moderately winter hardy.
- **Spice island:** Possibly the most aromatic rosemary, 'Spice Island' is sure to please. It has silver green foliage and grows up to 1 m tall.

Trailing and Creeping rosemary varieties

Prostrate forms of rosemary can grow in small mounds along the ground and even trail over the edge of a wall or pot. These make lovely border plants in flower beds or beautiful cascades of flowers trailing over the edge of a retaining wall. The following are some of the best creeping and trailing rosemary varieties.

- **Blue rain:** This variety is a wonderful trailing rosemary, great for growing at the edge of a wall or even in a hanging basket as it produces many downward trailing branches. It has grey-green foliage with medium-blue flowers.
- **Boule:** A lovely mounding and trailing rosemary with lilac-blue flowers and bright green foliage. It is considered semi-prostrate as mounds can reach 0.6 m tall. This is a robust variety that is relatively cold-hardy for a Mediterranean herb.
- **Capri:** As a very short, creeping rosemary, 'Capri' makes an excellent groundcover. It has bright green foliage and small, pale blue flowers.
- **Majorca pink:** Reaching only just over 0.5m tall, this variety is a very compact type. It is considered a semi-prostrate variety as it can also slightly cascade over the edge of a wall or pot. It has pink flowers and verdant green foliage. It is only moderately winter-hardy so it needs to be grown in a protected location for areas with hard freezes in the winter.
- **McConnell's blue:** As a low growing, creeping rosemary, 'McConnell's Blue' makes an excellent groundcover. It has light green foliage with an abundance of pale blue flowers.
- **Santa barbara:** This mounding creeping rosemary tops out at 0.3m tall, but can easily spread outwards 3 times its height. It has pale blue flowers and is reasonably cold-hardy.

Hardy types of rosemary

Hardy rosemary varieties can tolerate hard frosts and colder temperatures. Some can tolerate temperatures as low as -20° C. Here are a few popular cold-hardy rosemary varieties.

- **Alcalde:** 'Alcalde' cold-hardy rosemary is an upright variety that grows up to 1 m tall. It has pale blue flowers and olive-green foliage.
- **Arp:** This hardy upright rosemary can grow up to 1.2 m tall. While it is hardy in cold temperatures, make sure to plant in well-drained soil as it is sensitive to waterlogging conditions. It has grey-green foliage with light blue flowers.
- **Athens blue spires:** A very tall upright variety that is also a very cold-hardy. It can grow up to 1.5 m tall and has sky-blue flowers with grey-green foliage.
- **Barbeque:** As a hardy, upright rosemary, 'Barbeque' makes for a chunky shrub up to 1 m tall. Its wonderfully aromatic, bright green foliage is great for cooking.
- **Blue lagoon:** This variety is known for its bright blue flowers. 'Blue Lagoon' rosemary is quite cold-hardy and can grow up to 1.2 m tall.
- **Blue winter:** This is one of the most cold-hardy rosemary varieties. Its upright growth habit forms shrubs up to 1.0 m tall with blue-green foliage and light blue flowers.
- **Hill hardy:** Growing up to 1.2 m tall, this hardy variety has light blue flowers and grey-green foliage.

Soil and Climatic requirements

Rosemary plants thrives best in well-drained sandy loam soils. However, it can also be grown in clay loam soil or silty clay which has less than 25 % of clay. The crop requires acidic to neutral soil pH (5.5 to 8.0). It can't tolerate the soils having heavy clay percentage (not more than 25%). The soil properties influence the yield and the composition of rosemary oil. Rosemary requires Mediterranean type of climate with frost free cool winters and mild summer below 30°C. The crop can be cultivated in the lowers reaches of Himalayas (1000 meters' altitude).

Propagation

Rosemary is propagated by means of seeds, cuttings, layering or division of roots. Seeds germinate very slowly and growing true-to-type plants from seed is not a good practice as there is always a problem of cross pollination. Cuttings from actively growing stem tips are a good way to propagate new plants efficiently. Cuttings of 10 to 15 cm length should be collected and bottom 2/3 part should

be stripped from leaves. Then theses cuttings should be inserted in a proper growing medium. Rooting hormones will assist in root formation within 2 to 4 weeks. After roots have formed the plants can then be severed from the parent plant. Layering propagation can be achieved in summer season by pegging of some of the lower branches under a sandy soil. The plants can be served from the parent plant once root have been formed.

Field preparation

The field should be ploughed thoroughly and made free of weeds. After field ploughing through cultivator, harrow it thoroughly and separate it into beds of suitable sizes to facilitate irrigation. It is better to add 25 tonnes per hectare of well decomposed farm yard manure and recommended fertilizers as basal dose during the preparation of field and should be mixed well in the soil. The land should be irrigated a day before planting for successful establishment of plant cuttings.

Fertilizer application

A basal fertilizer dose of 40 kg ha^{-1} of phosphorus and potassium should be incorporated into the soil. A dose of 100 kg nitrogen per ha in three equal splits to be broadcasted at 4 months' interval. The first dose of nitrogen is given after two weeks of transplanting. However, the quality of the essential oil can be affected by application of excess inorganic fertilizer. In order to avoid the risk of quality losses, the chemical fertilizers may be replaced with organic fertilizers like composts or manures or enriched compost and manures.

Planting, Spacing, and Density

It is advised to plant rosemary rows in East-West direction as they need full sun light. When it comes to field, beds of 3 m x 3 m and row space at 60 cm x 45 cm are found effective with mechanized cutting. Plant density of 50,000 to 60,000 plants per hectare is required. The rosemary cuttings can be prepared in the green house or nursery and be transplanted to the main field in spring to mid-summer.

Transplanting

Rosemary cuttings get ready for transplanting within three to four months after rooting in the nursery. For the good plant establishment, it is advisable to transplant seedlings early in the morning or late in the afternoon to avoid the shifting shock. During transplanting, prepare a pit that is about 15 cm deep and 15 cm wide by keeping 60 cm spacing. Put seedling pots near to the holes. Cut the polyethylene plastic pots vertically with any sharp cutting tool. Put the seedling immediately into a pit. Take care not to detach the soil surrounding the

seedling root while transplanting. Cover the seedling hole with top soil gently; do not over press the soil while covering the roots since rosemary roots are sensitive to soil compaction. If the soil moisture is low irrigate the field immediately after transplanting.

Irrigation

Irrigation, at time of transplanting, is essential until the plants are well established. Rosemary can be grown in rain-fed conditions if rainfall is exceeding 500 mm per year. Under rain-fed condition, transplanting should be done at the onset of rainy season. Once the plant is well established on the field, it can cope with dry conditions. Whereas in under-irrigated condition, for the first three weeks after transplanting, irrigation may be applied once in every three days or at least once in a week depending on the availability of water. Subsequent irrigation need to done as per the need of crop and availability of water. Light irrigations are recommended to avoid water logging condition.

Weeding

Hand-weeding and hoeing are very important as weeds affect the yield and quality of herb and oil. Generally, 2 to 3 weeding are necessary during the year as per the weed infestation. Effective plant density and canopy will eliminate weeds after establishment of crop. Care should be taken not to damage roots as rosemary is very sensitive to root damage and causes plant to die back.

Diseases

Fusarium wilt

Symptoms of *Fusarium* wilt are dependent on several factors, including the amount of inoculum in the soil, environmental conditions, nutrients (particularly nitrogen), and susceptibility of the host. Wilting is followed by a yellowing of the leaves and finally necrosis. The wilting generally starts with the older leaves and progresses to the younger foliage. Soil fumigation with a broad-spectrum biocide like Methyl Bromide and chloropicrin etc. provides good initial control. Exclusion of the pathogen is also one of the best means of disease control. Cultural practices like long crop rotations, using disease-free planting material and disease resistance variety, exposing soil to the sun during summer months by deep ploughing, soil solarization and destruction of diseased roots are some of the practices which can reduce the disease. Use healthy seed treated with carbendazim (0.2%) can reduce the occurrence of the disease.

Powdery mildew

The symptom of this disease is an appearance of ash like white powder spread on the leaves. The disease occurs with excess soil moisture, improper soil aeration, high humidity and shady conditions. If the disease occur, cut overgrown branches to ensure better air circulations, allow the soil to dry out between watering sessions and minimize the amount of water application. With the initiation of disease, spray the crop with systemic fungicides like hexaconazole (0.05%) or carbendazim (0.1%) or difenoconazole (0.03%) and repeat at 10 to 14 days interval.

Root rot

The symptoms of this disease are wilting of leaves followed by dyeing of the whole plant and rotting of the roots. The disease occurs due to excessive moisture in the rosemary field as a result of poor drainage of soil, having a high clay content, and excessive application of fertilizers. Collect and destroy the infected plant debris, use healthy seed, follow long crop rotation, solarize field soil during summer months, amend the soil with neem or mustard cake and spray the crop with carbendazim (0.1%) or mancozeb (0.25%) or combination of mancozeb (0.25%) and carbendazim (0.05%) or tebuconazole (0.06%) and repeat at 10-14 days interval for foliar control of the disease.

Harvesting

The first harvest of leaves begins from 8 months after planting and subsequent harvests can be done at an interval of 3 to 4 months, depending on the geographical area and whether the harvest is for plant material or essential oil. Annually, three to four harvests can be taken and this perennial crop can be retained for up to twelve years based on the vigour of the crops. Harvest will commence at the time of 50% blooming and continues till 75 – 90% inflorescence emergence and must end when the flowers have finished blooming. More often harvesting is done by farmers with mechanical harvesting. The plants yield more material from frequent re-growth. Harvest rosemary using a well sharpens cutting tool by taking maximum care not to disturb the roots of rosemary. Harvest rosemary branches about 15 cm above the ground by leaving growing point (nodes) below the cutting point. Improper harvesting will lead to death of plants.

Distillation

Essential oils, being volatile in nature, are extracted from freshly harvested twigs or leaves by the process of steam-based distillation. The herbage can also be shade dried, stored and distilled at convenience without any loss of soil. A

continuous distillation for 2 hours at 2-3 atmospheric pressure is sufficient to recover most of the essential oil.

Oil content and Yield

Under laboratory conditions, the fresh rosemary leaves yield about 1% oil and shade dried leaves about 3% oil. However, in commercial field distillation units, oil recovery is only 0.8%. About 12 to 15 tonnes of fresh herbage from one hectare of cropping can be obtained in one year thus giving a yield of about 85 to 100 kg of oil per hectare per year.

Quality standards

The standard set by the International Standard Organization (ISO) known by its identification number (ISO 11164:1995), states the quality requirements for dried rosemary. According to the ISO standard the dried leaves of rosemary should contain a minimum of 1.2 % volatile oil, maximum of 10.0 % foreign matter, maximum of 2.0 % woody stems, and a maximum of 7.0 % ash.

Thyme

Thyme belongs to the family of 'Lamiaceae' and its scientific name is "*Thymus vulgaris* L.". Thyme is a hardy perennial shrub with 20-40 cm high. It has both horizontal and upright habits. The stems become woody with age. Leaves are almost stalkless with margins curved inwards and highly aromatic. The fragrance of its leaves is the result of an essential oil, which gives its flavouring value for culinary purposes and is the source of its medicinal properties. The flowers terminate the branches in whorls. The calyx is tubular, striated, closed at the mouth with small hairs and divided into two lips, the uppermost cut into three teeth and the lower into two. The corolla consists of a tube about the length of the calyx, spreading at the top into two lips of a pale purple colour, the upper lip erects or turned back and notched at the end, the under lip longer and divided into three segments. The seeds are round and very small and retain their germinating power for 3 years. Aerial parts are used for essential oil production mostly by steam distillation. The fresh and dried herb market uses it for culinary purposes. The major types of thyme available in the international market are French Thyme, Spanish Thyme and American Thyme.

Fig. 3.3: Thyme planting

Fig. 3.4: Thyme

Origin and Distribution

The name thyme, in its Greek form, was first given to the plant by the Greeks as a derivative of a word which meant '*to fumigate*,' either because they used it as incense for its balsamic odour or because it was taken as a type of all sweet-smelling herbs. Others derive the name from the Greek words *thyo* meaning perfume or *thumus* signifying courage, the plant being held in ancient and medieval days to be a great source of invigoration, its pleasant qualities inspiring courage. Another source quotes its use by the Sumerians as long ago as 3500 BC and to the ancient Egyptians who called it *tham*. Thyme is a native to Southern Europe from Spain to Italy. Apart from Europe, it is grown in Australia, North Asia, North Africa, Canada and USA. In India, it is cultivated in the Western temperate Himalayas (from Kashmir to Kumaon) and to the stretch of Nilgiris.

Uses

Thyme is used to season, tomato soups, juice fish and meat dishes. It is also used in liver and pork sausages, head cheese, cottage and cream cheese. It possesses properties. The oil of thyme is well recognized for its medicinal properties. It has anti-spasmodic, anti-oxidant, anti-microbial, and carminative properties. It is employed in preparations use for the treatment of bronchitis and whooping cough. The oil of wild thyme is applied in toothache.

Vernacular names

Hindi: Banajwain, Malayalam: Thottathulasi, Punjabi: Marizha, Masho, Rangsbur, Urdu: Hasha

Cultivars

The genus Thymus has about 215 species and numerous hybrids as well. Three principal varieties are usually grown for use, the broad-leaved, narrow-leaved and variegated. The narrow-leaved type, with small grey-green leaves, is more aromatic than the broad-leaved and is also known as winter or German thyme. The fragrant lemon thyme has a lemon flavour and rather broader leaves and without curved at the margins than the ordinary garden thyme which ranks as a variety of the wild thyme i.e., *Thyme serpyllum*. The silver thyme is the hardiest of all and has the strongest flavour.

Listed below are the most cultivated thymes used for culinary and essential oil extraction. As the plant hybridizes easily, there are many different types available:

- ***T. vulgaris*** - A common thyme which have a prostrate form. It has yellow, silver and variegated foliage available and is used in cooking.
- ***T. zygis*** – This thyme is same like the above and is mostly distilled for essential oil.
- ***T. x. citriodorus*** – This is a lemon thyme. It has an upright form. It has golden and variegated silver foliage available and have a strong lemon scent.
- **Varico**, a robust cultivar, has an upright growth form with greyish-blue foliage and excellent herbage yield. It produces thymol levels of 50 % and higher as well as more than 3.0% essential oil yield. It also has a good resistance to frost. It can be propagated with seed.
- Other promising new cultivars are currently developed in various countries.
- Various species and hybrids have been selected for the colour of the leaves and flowers and are mainly used as ornamental shrubs.

Soil and Climatic requirements

Herbal and essential oil crops grown on neutral soils yield more end products that are of high quality and global demand. Thyme prefers light, well-drained soils and calcareous soil with a pH of 5.0 to 8.0 for good growth and oil content. Excess moisture for longer period in heavy soil causes wilting of plants. The soil in hilly areas, where water usually drains very fast, is ideal for the growth of thyme. Thymes are susceptible to frost. They thrives in a moderate to warm, dry, sunny climate with no shadow. It needs full sun to grow to its best potential. Rainfall in the Mediterranean region, where thyme use to cultivate, is 500 to 1

000 mm per year mainly in winter. Thyme prefers a mild climate, a mallow upland soil and grows best in the hills. Planting thyme in gardens is commonly practiced as it adds aesthetics and can be trained to look beautiful while also used for culinary purposes.

Propagation

Thyme is propagated from seeds, stem cuttings, and layering. Plantations may also be increased by dividing the plants at their roots. Seeds must be sowed in spring to a depth of 6 mm or less. Seeds germinate in about 2 weeks. When planted in seed trays, it will take 6 to 8 weeks to reach transplant readiness. The seedlings should be transplanted out of doors after the danger of frost has passed. If established and growing well before winter, the small plants can withstand frost. The source of thyme seed has to be known as there are possibilities of hybridization. To have homogeneous plants, it is advisable to make cuttings. Thyme grows easily from 5 to10 cm cuttings taken in spring by using rooting hormones. Propagation through cutting is not advisable in sick soil loaded with soil borne pathogens. The best time for propagation is the month of March and April.

Field preparation

Thyme can be planted successfully in soil that is very shallow and where other crops cannot survive. The preparation of land should also be done according to the variety that has been selected for cultivation. The land is prepared well by repeated ploughing or digging and brought to smooth and fine tilth. Then, the land is divided into plots so as to make drainage convenient in the main field.

Planting, Spacing, and Density

When the seeds are sown directly, they can be sown in rows 90 cm apart and later, when the seeds germinate, the seedlings may be thinned out to 30-45 cm within the row. While planting the seedlings or rooted cuttings or layers etc., the spacing may be 30-45 cm apart in rows with a row width of 60 cm apart. Care must be taken on not to squash thyme as it will break the woody stem at soil level and the plants may die off. Thyme can also be planted with a special planter that can plant small seed. There are 3300 to 4000 seeds per gram. Seedlings can also be raised in a nursery using plant trays. Plant density can be adapted according to the size of mature plants and moisture availability. The best times to sow or plant seed and transplant cuttings is spring but in some cases, it is done before winter. Small seedlings can be more frost resistant than mature plants. Transplant when the plants are 3-4 inches tall. A light irrigation is provided after planting.

Irrigation

Thyme loves moist soil but does not like too much wet. Irrigate sparingly and ensure that there is no water stagnation.

Fertilizer application

Application of well decomposed FYM is done at the time of preparation of land. Fertilizers are applied @ 100:40:40 kg NPK per hectare. A top-dressing of N and FYM in spring is reported to promote the formation of numerous leafy shoots. Thyme should not be fertilised heavily because over fertilised plants tend to show tall, spindly, and weak growth. Do not give excessive nitrogen because the quality of the oil may be affected.

Weed control

Weeding are done at regular intervals to encourage the good growth of the plants. Thyme can be established successfully, without herbicides, by planting the crop in a land covered with weed-suppressing plastic mulch. Organic mulches and hand-weeding are also used. The crop has to be kept weed free so as to avoid contamination of the end product.

Diseases

Root rot (*Rhizoctonia solani*)

The symptoms of this disease include wilting of leaves followed by dyeing of the whole plant and rotting of the roots. The disease can occur due to excessive moisture content in the field due to poor drainage of soil as a result of high clay content and excessive application of fertilizers. Collect and destroy the infected plant debris, use healthy seed, follow long crop rotation, solarize the field soil during summer months, amend the soil with neem or mustard cake (250gm^2), and spray the crop with Carbendazim (0.1%) or Mancozeb (0.25%) or combination of Mancozeb (0.25%) and Carbendazim (0.05%) or Tebuconazole (0.06%) and repeat at 10-14 days interval for foliar control of the disease.

Botrytis rot (*Botrytis cinerea*)

Botrytis blight causes buds and flowers to develop abnormally and turn brown. Flowers may have irregular flecks and brown spots. Older flowers tend to rot quickly. Soft, brown spots appear on leaves, stem, and flowers following a cool damp period. With a further cool damp weather, the affected parts may be covered with a grey mold. Collect and destroy the infected plant debris, avoid overcrowding**,** follow crop rotation and spray the crop with Captan (0.25%) or Mancozeb (0.25%) and repeat at 10-14 days interval.

Alternaria blight (*Alternaria brassicicola*)

The most characteristic symptom of this disease is the dark brown spots with concentric rings that develops on the leaves and give a target board effect. In humid weather, the affected areas coalesce and form dark brown patches. In severe attacks, affected leaves shrivel and fall down prematurely resulting in early defoliation. Collect and destroy the infected plant debris, follow crop rotation, select healthy seed and treat it with Captan (0.3%), spray the crop with Chlorothalonil (0.2%) or Mancozeb (0.25%) and repeat at 10 to 14 days interval.

Harvesting

The leaves and flowers, which are used for culinary and medicinal purposes, are harvested five months after sowing/ planting. The leaves and flowers are plucked from the plants or shoots of about 15 cm, which are cut off from the plants, dried in the shade or in a dryer immediately after harvest and stored in air-tight containers to prevent the loss of flavour. The dried leaves are curled, are brownish-green in colour and are usually not longer than 6-7 mm. The dried shoots may also be powdered and packed. Under favourable conditions, the yield of dry herb is around 1,100-2200 kg per hectare. The yield is comparatively low during the first year. The plants become woody and their replanting becomes necessary after three or four years. For extracting the oil, the fresh herb is collected on dry days. The herb is collected at the stage, when it just start flowering. At the time of collection, the lower portions of the stem along with any yellow or brown leaves, need to be rejected.

Distillation of oil and oil yield

The oil is distilled from the fresh flowering tops by steam distillation. The herb contains about 2.0% essential oil and the oil recovered by distillation is about 21.0 kg per hectare.

Activities

Visit a nearby any herbal spices field.

Material required: Pen, Pencil and notebook etc.

Procedure: Write the following observation during visit

- Name of the crop & variety
- Spacing adopt
- Approximate height of plant
- Date of sowing, time of flowering, fruiting and harvesting.

Check Your Progress

A. Fill in the blank

1. Rosemary belongs to the family of.....
2. CIMAP stand for...
3. Ooty-1 is a variety of.....
4. The rosemary cutting prepared in nursery and transplant to the main field in .....
5. Thyme is propagated from....., ... and .....
6. The oil of thyme is distilled from the fresh flowering tops by..... distillation.

B. Multiple Choice Questions

1. The native place of rosemary is...

   (a) Mediterranean region

   (b) Middle East

   (c) China

   (d) India

2. How many times the rosemary crops are harvested in a year?

   (a) Two time

   (b) Three time

   (c) Four time

   (d) Eight time

3. Thyme belongs to the family of...

   (a) Labiatae

   (b) Apiaceae

   (c) Lamiaceae

   (d) Leguminosae

4. The name of common thyme is...

   (a) Thymus vulgaris

   (b) Thymus zygis

   (c) Thymus citriodorus

(d) Thymus varico

C. Subjective Questions

1. Describe the cultivation practices of rosemary under following heads.
   - Soil and climatic requirements
   - Propagation, planting and spacing
   - International varieties (Upright-growing types of rosemary)
2. Describe the cultivation practices of thyme under following heads.
   a) Origin and distribution
   b) Cultivars
   - Insect-pests and diseases
   - Harvesting

Session 2: Cultivating Oil Yielding Spices

Ocimum (*Ocimum basilicum*)

Ocimum basilicum Linn. occur naturally as a tetraploid (2n=48). It is a large, herbaceous, erect, strongly aromatic annual herb raises to a height of 30-90 cm and belongs to the family *Lamiaceae*. Opposite arrangement of leaves having ovate-lanceolate structure with 3.75-5 cm long; petioles very slender typically slightly hairy; flowers 0.72-1.25 cm long, born in racemose inflorescences, corolla 0.72 - 1.25 cm long, white, pink or pale-purplish, bracts are petiolate, flowers are conspicuous, seeds black and ellipsoid that when moist, turn mucilaginous.

Fig. 3.5:
Ocimum basilicum

Fig. 3.6:
Ocimum basilicum

Origin and Distribution

The genus *Ocimum* is well-represented in the warmer regions and distributed to 1800 m altitude from the sea level. The key centres of diversity in this genus are in Africa, South America (Brazil) and Asia and grow mainly in France, Italy, Bulgaria, Egypt, Hungary, South America, Comoro Islands, Thailand, India, Haiti and Guatemala. It is indigenous to the lower hills of Punjab and Himachal Pradesh and is cultivated throughout the India. The cultivation of French basil is mostly concentrated in Uttar Pradesh.

Uses

Ocimums are significant groups of aromatic and medicinal plants which yield many essential oils and aroma chemicals and find diverse uses in perfumery and cosmetic industries as well as in Indian System of Medicine (ISM). Among various *Ocimum* species, *O. basilicum* is commercially and extensively cultivated for essential oil production. The dried leaves and tender four sided stems are used as spice for flavouring of food and for essential oil extraction. The essential oil contains methyl chavicol, linalool, 1, 8-cineole and methyl cinnamate as the major components. Its oil is employed for flavouring of food stuffs, confectionery, condiments, perfumery industry, and in toiletry products. Apart from flavouring of numerous foods, it is used for seasoning in tomato paste products. The sweet basil oil is widely used in perfumery compounds. Besides the medicinnal use, it also used as an insecticide and bactericide.

Vernacular Names

Sweet basil / French basil (English), Babaui tulsi (Hindi); Damro, Damarvo (Gujarati); Barbari, Arjaka (Sanskrit); Tirunittur (Tamil); Kamakasturi (Kannada); Bhutulasi (Telugu); Babri (Punjabi).

Types and Varieties

In view of the great diversity, the various species and varieties have been classified, in accordance with their chemical composition and geographical sources into 4 major types as given here under.

1. European or sweet basil: The oil obtained from this type consist of mainly methyl chavicol and linalool, but no camphor. This group comprises French and American Sweet basil oils which are in demand because of high quality and the finest odour. It is distilled in France, Italy, Bulgaria, Egypt, Hungary, and South Africa, and occasionally in the United States.

2. Reunion basil: The main constituents of the oil obtained from this type are methyl chavicol and camphor, but no linalool. The oil is somewhat of lower

quality. It is distilled in the Reunion Island, Comoros, Malagasy Republic, Thailand and occasionally in the Seychelles.

3. Methyl cinnamate basil: The oil obtained from this type consist of methyl chavicol, linalool and with the presence of methyl cinnamate in substantial amounts. It is distilled in tropical countries like India, Haiti, Guatemala and a few African countries.

4. Eugenol basil: Eugenol is the principle constituent of the oil. It is distilled in U.S.S.R. and North African countries like Egypt and Moracco.

Nine species are recorded in Eugenol basil from India of which three are exotic. The more important of these species are:

a) *Ocimum basilicum* Linn (2n=48) (English / French / Sweet Basil)

It has the following subspecies and varieties.

1. *O. basilicum* Linn. Subsp. minima Danert (Syn. *O. minima* Linn)
2. *O. basilicum* Var. majus Benth
3. *O. basilicum* Var. difforme Benth (Curly - leaved basil)
4. *O. basilicum* Var. purpurascens Benth (Violet - red basil)
5. *O. basilicum* Var. glabratum Benth (Common white basil)
6. *O. basilicum* Var. *pilosum* Benth (Syn. *O. pilosum* Roxb)
7. *O. basilicum* Var. crispa
8. *O. basilicum* Var. thyrisiflora
9. *O. basilicum* Var. darkopal

b) *O. americanum* Linn. (Syn. *O. canum* Sims.) (Hoary Basil)

c) *O. gratissimum* Linn. (Shrubby basil)

d) *O. kilimandscharicum* Guerke (Camphor basil)

e) *O. sanctum* Linn. (Sacred or Holy Basil)

f) *O. viride* willd (Fever plant of Sierra Leone)

Of the above listed species, *O. basilicum* Linn. is the only commercially cultivated species in India.

Varieties like RRL-011, Vikarsudha, Kusumohak and Cim-Saumya have been released from different institutes.

Soil and Climatic Requirements

Sweet basil can be cultivated on a wide range of soils - from moderately fertile, well drained loamy to sandy loam soils - with a pH ranging from 4.3-9.1 except clayey, water-logged soils that are unsuitable. It is tolerant to higher concentration of copper and zinc, but is susceptible to cobalt and nickel. Crop comes up well in warm and humid climate up to an altitude of 1800 m. Long day, high temperature and high humidity have been found favourable for plant growth and high oil production. The plant is also susceptible to frost. The crop growth is poor in areas which receive heavy and continuous rainfall. In such areas the crop could be raised prior to the onset of monsoon and care should be taken that the rain water does not stagnate in the field. Water logging causes root rot and result in stunted growth.

Propagation

The plant is propagated through seeds, but direct sowing of seeds in the field is not advisable. Seedlings are first raised in the nursery and then transplanted to the field. This plant is highly cross pollinated and gets deteriorated over generations in quality oil yield. Hence, for planting, grower has to collect fresh seeds from the pedigree stock which are in good condition and free from pests. About 125 g seeds are required for raising seedlings in one hectare.

Nursery

Raised seed beds of 10 – 15 cm height should be thoroughly prepared by the addition of well rotten farmyard manure and leaf mould each at the rate of 1 kg per square meter and mixed it well into the soil. Beds of 1 m × 4 m with irrigation channels are laid out and seeds (10-15 g per bed) are mixed with fine sand or wood ash and sown in lines of 6 cm apart or broadcast over the beds. The seeds are then covered with a thin layer of fine soil or farm yard manure. The nursery beds are watered immediately after sowing and should be regularly watered thereafter. In the plains of North India, the seeds may be sown in the nursery in the months of April-May or August-September and in the hilly regions' seeds are sown in the month of April. The seeds start germinating 3 days after sowing and the germination will be complete in about 8-12 days. The seed bed should be kept weed free. The seedlings will be ready for transplanting in about 6 weeks after attaining a height of 10-15 cm. A spray of 2.0% urea solution to the nursery plants at 15-20 days before transplanting helps in getting healthy and vigorous seedlings.

Vegetative propagation:

It can also be propagated by vegetative means using terminal cuttings and about 90-100 per cent success when planted during October-December months in Southern India. In this method, cuttings with 8-10 nodes having 10-15 cm are suitable for vegetative propagation. All the leaves remove from the cuttings except 2-3 pair of terminal leaves. These are planted in the well prepared nursery beds or polythene bags. About 4-6 weeks' time is required for complete rooting and then it is being transplanted into the field. Rooted cuttings are transplanted at a distance of 40 cm apart between the rows.

Land preparation

The land is brought to fine tilth and laid out into plots of convenient sizes. It is preferable to add 10-15 tonnes per hectare of farm yard manure and recommended fertilizers as basal dose during the preparation of land and should be mixed well in the soil. Among the chemical fertilizers, application of 120:60:60 kg ha^{-1} of NPK is recommended for good growth.

Planting time

The crop can be grown from the middle of February to the end of September and also during *Kharif* in plains of North or South India. In the hilly areas of north India, the crop can be grown during *Kharif*.

Transplanting

The seedlings of six weeks old which are having a height of 10-15 cm are transplanted in the main field. Transplanting should be done preferably in the evening hours to avoid shifting shock. Spacing of 40-60 cm is ideal for sweet basil cultivation. Cloudy weather and fine drizzling are considered ideal for transplanting.

Fertilizer application

Farm yard manure/ compost are to be applied at 10 tonnes per hectare before planting. Ensure that FYM/ compost is well decomposed before use. Do not use compost made from city waste and human excreta. Avoid the application of fresh manure as it must be well decomposed. A medium fertilizer dose of 40:40:40 kg per hectare of N, P_2O_5 and K_2O is recommended for economic yield, though good response can be received up to 120:100:100 kg per hectare. This crop is tolerant to higher concentration of copper and zinc but susceptible to cobalt and nickel.

Irrigation

When this crop is raised as a summer crop, irrigation is required once in a week. But, with the onset of monsoon, irrigation is not required till September.

Thereafter, the crop needs irrigation once or twice a month. In total, 12-15 irrigations are required during a year. Apply mulch to conserve soil moisture. However, before harvesting, irrigation should be discontinued.

Intercultural operation

Normally, the seedlings get well established in the field one month after transplanting. First weeding is done at this stage and second weeding is done 4 weeks after the first. No further weeding is required thereafter as the plants become bushy and thereby suppress the weeds. In large plantation, the expenditure on weeding can be minimised by the use of cultivator drawn by tractor. Hoeing is done two months after planting. The crop may also be earthed up at this stage. Use mulch to maintain moisture in the soil and to inhibit growth of weeds. Do not use chemical herbicides to eradicate weeds and also avoid excessive weeding which can cause soil moisture loss.

Plant protection

Sweet basil is found to be infested with few insect pests and diseases. Medicinal plants like sweet basil require production involving minimal or no usage of chemical pesticides. Organic practices include control measures using neem based formulations. Fish oil resin soap can be used to manage such sucking pests. Botanicals viz., extracts of garlic, *Vitex negundo*, *Lantana camera*, *Clerodendron inerme*, *Calotropis gigantean* are often combined and sprayed periodically for controlling the pests.

Pests and Diseases

Insects – Pests

Leaf rollers: Leaf rollers, sticking to the under surface of the leaves, folds them backwards length wise and web them together. This can be controlled by spraying with 0.2% Malathion or 0.1% Methyl parathion whenever noticed.

Bug (*Monanthia globulifera*): It causes leaf curling. Spray Azadirachtin 10,000 ppm @ 5 ml^{-1} to control this insect.

Diseases

Leaf spot (*Corynespora cassicola*): Disease appears as small water soaked spots which later turn brown in colour. Destruct infected plant debris, use of clean seed and spray the crop with carbendazim (0.1%) or mancozeb (0.25%) and repeat at 15 days interval.

Scab (*Elsinoe arxii*): Disease causes puckering and dipping of the leaves and distortion of the tender twigs. Seedlings can be disinfected by dipping them for 10 minutes in Emisan (0.25%).

Blight (*Alternaria sp.*): It is an important disease which starts with a chlorotic appearance on the leaves which turns purple and finally black. Later on leaves are shed. *Colletotrichum capsici* also causes leaf blight. The disease appears as small chlorotic spots on the leaves which enlarge rapidly. Older leaves appear to be more susceptible to infection. Disease can be effectively managed by foliar spraying of Bordeaux mixture 1% at 15 days interval.

Wilt (***Fusarium oxysporum***)*:* It can occur at all stages of growth. The disease is more pronounced in rainy season. Initially, the leaves wilt but soon spreads to the whole plant. To control the disease, seedlings should be dipped in a solution of tafason or agallol (0.25%) at the time of planting. Use healthy seed and treat with carbendazim (0.2%).

Harvesting

Care should be taken while harvesting the sweet basil to avoid any type of contamination at this stage. Clean all the surfaces that come in to contact with the plants during and after harvest. Time of harvest plays an important role in qualitative and quantitative oil production. Harvesting is usually done in bright sunny days for good oil yield and quality. It is not desirable to harvest the crop, if there is a rain during the previous day. The crop is harvested at 90-95 days after planting, in a stage, when the plant is in full bloom and the lower leaves start turning yellowish. Harvesting is done with the help of sickles. Corresponding to the part harvested, two grades of oil can be obtained i.e., herb oil and flower oil. The flower oil has a superior note. For getting the high quality oil only the flowering tops are harvested. Normally 3-4 floral harvests are obtained in this crop. The first harvest is taken when the plants are in full bloom and the subsequent harvests at 65-75 days interval. The whole plant is harvested after leaving about 15 cm from the ground level for further regeneration of the crop. The harvested produce will be allowed to wilt in the field for 4-5 hours so as to reduce the moisture and also the bulkiness.

Yield

An average yield of 3.0 – 4.0 tons of flowers and 13-14 tons of herbage can be obtained per hectare. The inflorescence contains 0.4% essential oil while the whole herb contains 0.10 to 0.25% which gives to an oil yield about 30-35 kg ha^{-1} from flower (flower oil) and 18-22 $kgha^{-1}$ from whole herb.

Post-Harvest management

Post-harvest processing is usually the most critical stage in determining the end quality of the aromatic plants. Oil of Sweet basil is obtained by hydro-distillation or steam distillation of young inflorescence or the whole herb. Extraction of oil

through steam distillation is better than hydro-distillation as it takes less time and improves the oil recovery. Hydro-distillation can be carried out by direct heating and is cheaper and handy for small plantations, while steam distillation is preferred for larger plantations. Distillation unit should be clean, rust and odour free. The oil obtained is then decanted and filtered. The distilled oil is treated with anhydrous sodium sulphate or common salt at the rate of 20.0 g per litre to remove the moisture. The oil should be stored in sealed amber coloured glass bottles and containers made of stainless steel and aluminium, and galvanised tanks in a cool and dry place.

Mint (*Mentha species*)

Mint (*Mentha species*) is a spice and its various species are for commercial use. Being a high value crop, its export opportunities are abundant. It is used for flavouring of food stuffs. It is also used in medicines, cosmetics, perfumery industries. This spice comes under indispensable segment of culinary and hence, it essentially add flavour, colour and taste to the cuisine. India is a leading country for the production of this spice and its 90.0% consumption is within the country while about 10.0 % of rest of the produce are being export to around 150 countries accounting 10.4 million tons. The 10% export meets out the 50% world spices demand. Out of 109 spices, India produces more than 65. The major importing countries are USA, Europe, Australia, Japan and Middle East including Oceanic countries. Besides India, major other producing countries are China and Japan. India exports around 25,000 to 30,000 tonnes menthe products (menthol crystals and powder, dementholized mint oil etc.), with the balance of production used domestically. Likewise other spices, mint consumption in India is about 40% of global produce whereas China, Europe and USA consume annually 20, 15, and 15% respectively.

Fig. 3.7: Mint

Fig. 3.8: Mint

Vernacular names: Pudina in Hindi, Kannada, Telugu and Marathi; Puthina/Pudhinaa in Tamil; Hara Pudina in Punjabi; Fudino / Phodina in Gujarati; Putiyina/Pudhinaa in Malayalam; Pudyanu in Kashmiri.

Botanical description

Genus 'Mentha' is perennial herbs belong to the family *Labiatae* (*Lamiaceae*). Its stolons, spread either underground or over ground, are erect, square and stems are branched. The arrangement of leaves is in opposite pairs. These are oblong to lanceolate and having downy and serrated margins. Leaf colours range from dark green and grey-green to purple, blue, and sometimes pale yellow. It bears abundant verticillasters, called as false whorls, which produces white to purple flowers. The corolla is two-lipped with four subequal lobes and among them upper lobe usually the largest. The fruit is a nutlet containing one to four seeds and some of the species does not produce seeds thereby propagated trough vegetative stolons.

Origin and Distribution

It has been originated from Mediterranean basin. And from that basin, it had spread worldwide either naturally or artificially. Among all the mints, Japanese mint is cultivated on a large area in Brazil, Paraguay, China, Argentina, Japan, Thailand, Angola and India. Japanese mint grows large scale in USA, Morocco, Argentina, Australia, France, USSR, Bulgaria, Czechoslovakia, Hungary, Italy, and Switzerland while on a small scale in Europe countries. Peppermint and spearmint are majorly produced in USA. Mentha cultivation on commercial scale is in Indo-Gangetic plains of Uttar Pradesh and also in Punjab and Haryana. Mentha production in U.P. contributes about 95 per cent and rest comes from other states. Barabanki, Rampur, Moradabad, Bijnor, Jyotiba Phule Nagar, Pilibheet, Bareilly, Badaun, Shahjahanpur, Sitapur, Hardoi, Unnao, Faizabad, etc. are the mentha producing major districts of Uttar Pradesh.

There are four cultivated species:-

1. Japanese Mint/Menthol Mint (M. arvensis),
2. Peppermint (M. piperita),
3. Spearmint (M. spicata) and
4. Bergamot mint (M. citrata).

Japanese mint (*Mentha arvensis var. piperascens*) is an aromatic herb of temperate region. It has menthol, an aroma-compound, which have cooling and gastro-stimulant properties and is used in pharmaceuticals, food flavour, confectionery, cosmetics, beverages and related industries.

Varieties: These are - MAS-1, Hybrid-77, Shivalik, EC-41911, Gomti, Himalaya, Kosi, Saksham, Kushal, Sambhav and MA-2.

Peppermint (*Mentha piperita*): It has long- stalked opposite lanceolate leaves. Plants, being 50-80 cm tall, bears globular flowering spikes and have purplish blossom in their terminal spikes. Black Mitcham variety is common and prefers cool sub-temperate climate for growing. The cultivation practices are similar to those of Japanese mint. While it has lower oil content (0.25%), the average oil yield is being 80 kg per hectare from a fertile land having well-managed crop. It is mainly used in pharmaceutical preparations. Peppermint oil constituents are almost similar to Japanese mint except menthol content is lower than that.

Varieties: Kukrail, Pramjal and Tushar, CIM Indus, CIM Maduras

Spearmint (*Mentha spicata*) is another important mint. Its oil is rich in carvone (65%) content and emits caraway like odour. The oil is used in dentifrice, confectionery and pharmaceutical products. It bears lanceolate stalk less with light green leaves. It has a narrow, long, terminal flowering spikes with lilac flowers and attains 60 cm a height. The important constituent of spearmint oil is carvone (57.71%) and the other micro constituents are phellandrene, limonene, L-pinene and cineole. The major use of oil is for flavouring foods, toothpastes, pickles and spices, chewing gum and confectionery, soaps and sauces.

Varieties: MSS-5, Arka, Neera, Ganga, Neerkalka, MSS-1, and Punjab Spearmint-1.

Bergamotmint: It is also known as lemon mint (*Mentha citrate*) and is robust like Japanese Mint. It bears similar broad ovate leaves without distinct inflorescence. The oil has an odour like lavender oil by high Linalool (45-50%) and Linalyl Acetate (45%) contents. The yield of herb and oil is similar to Japanese mint. The oil mainly used in perfumes and cosmetic preparations. Linalool and Linalyl Acetate are the main constituents of this oil.

Varieties: Kiran-A high-yielding variety produces about 150 kg of oil ha^{-1}.

Soil and Climatic requirement

Mint can be cultivated in wide range of soils, however loam or sandy loam or deep soils rich in organic matter are the best for cultivation. It thrives well in fertile soil with pH range of 6.5-8.0. In acidic soils having pH 5.5, liming is recommended. Clay soils with high pH (>8.50) and frost prone areas are not suitable for its cultivation. It is a shallow- feeder crop required fertile surface soil. The soil must be well drained and should have loose textured to get better growth and desired yield of mint. Sufficient drainage is required where there is

a high water table between 60 and 100 cm. It can grow on elevation up to 1,000m in subtropical northern India. The optimum temperature for its cultivation is 20.0˚C to 40.0˚C, whereas it requires rainfall between100.0 to 110.0 cm is most appropriate. Light showers at planting time and good sunny days at harvesting stage are the best for its high yield and quality of leaves.

Propagation and Seed rate

Mint can be propagated vegetatively through root suckers and terminal cutting (stolon). About 4 quintals of stolons are required for planting in a hectare.

Field preparation

The land is ploughed using harrow to make a fine tilth and weed free. After field ploughing through cultivator, harrowed thoroughly and divided into beds of suitable sizes to facilitate irrigation. At the time of land preparation, about 25-30 tonnes per hectare of farmyard manure together with 25kg of BHC (10%) is applied. Lines are opened on each bed at 40x 40 cm apart depending upon the variety and inter-culture implement are used. The depth of furrows should be 5 to 6 cm and within a furrow stolons are placed at 10 cm distance and thereafter furrows are closed with top soil.

Planting time and method

In northern India, planting of Japanese mint is suitable from 1st week of February to 2nd week of March. The stolons are cut into 7-10 cm and dipped in 0.1% Agallol or Captan solution for 2-3 minutes before planting. Stolon should be planted in shallow furrows about 7-10 cm deep with a row-to-row distance of 45-60 cm. Stolons should be planted half-way down on the inner sides of the ridges, while planting on ridges. A light irrigation is required immediately after planting of stolon. If it is grown as a perennial crop, the first year crop is called as 'Row mint', while the second and third year crop is called 'Meadow mint'.

Fertilizer requirement

Mint responds well to nitrogenous fertilizers being a foliage crop. General requirement of nitrogen is 80-120 kg, Phosphorus 50 kg as P_2O_5 and Potassium, as K_2O, is 40 kg per hectare is the requirement for a good crop. Moreover, *M. arvensia* responds up to 160 kg of Nitrogen per hectare and in *M. pipereta* up to 125 kg of Nitrogen per hectare for higher herbage and essential oil-yield. Nitrogen may be applied in three split doses: First dose at the time of soil preparation, second dose should be 2 and 3 months after planting, and the third dose after the first harvest of the crop. However, P and K should be applied as a basal dose at the time field preparation. Fertilizers and manure should be applied on soil test basis for both yield and quality of crop and environment. In some of the

places crop does not respond to potassium fertilizers. However, in some pockets, boron and zinc deficiency reduces both the yield of green herb and the essential oil in peppermint, hence should be applied accordingly on soil test basis.

Irrigation

The water requirement of mint is quite high and frequent. Based upon the soil and climatic conditions, the crop requires 6-9 irrigations before the onset of monsoon. The crop requires at least three irrigations during post monsoons period in September, October and November. Plants are dormant during winter season, hence there is no requirement of any irrigation. In northern India, fifteen irrigations are required to get the maximum herb and oil-yield of Japanese mint.

Weeding

Without proper weed management or inter-culture operations, 60% reduction is observed in herb and oil yields. Hence, mints require weeding and hoeing at regular intervals at early growth stages of crop. At least one hand-weeding is required after the first harvest. Sinbar can be applied as a post-emergence spray @ 1 kg ha^{-1} controls weeds effectively. However, combining organic mulch along with 0.5 kg ha^{-1} of Oxyfluorfen including hand weeding or application of Pendimethalin @ 1 kg ha^{-1} along with weeding controls weed growth effectively.

Crop rotation

The rotation of mint is needed like other crops for control of weed growth, insect-pest and diseases management, and preservation of soil fertility. Continuous cropping of any of the mints is not recommended. Crop rotations are location specific and vary with place to place. Some of the crop rotations like mint-rice/wheat, mint-potatoes, mint-rapeseed/mustard, mint-maize, mint-vegetables/peas etc. are the best.

Pests and Diseases

Pest and diseases infestation vary place to place, however some common of them under Indian conditions are given hereunder along with suitable control measures.

Insect-Pests

The important pests are leaf-roller, pyralid moth, the hairy caterpillar and, termites. Hairy caterpillar (*Diacrisia obliqua* Walk) defoliates the crops during the months of April-May. Dipterex (5%) spray is required to control this caterpillar. During the dry months, termite attacks are often observed. This can be controlled effectively by application of 3% Heptafan @ 50 kg ha^{-1} to the soil before planting. Other pests like cut-worm (*Aulucophora favicollis*) can be controlled by

spraying Thiodon. Nematodes can be effectively controlled by the application of neem cake @ 250 kg ha^{-1} in the soil. Red pumpkin beetle could be controlled by spraying Malathion @1 ml per litre of water. However, in Southern India, no major pest and disease has been reported so far.

Diseases

Stolon rot is very serious disease and could be managed by treatment of stolons with 0.25% captan or 0.1% benlate or 0.3 % agallol solution for 2 to 3 minutes before planting. Fusarium wilt can be control by application of 0.1% Benomyl (Benlate) or Bavistin (Carbendazim). While Leaf blight, could be managed by application of 0.25% copper oxy chloride (2.5gm per litre).

Harvesting

First cutting starts in about 5 months after planting and subsequently at 3 months interval depends on soil fertility and climatic conditions. Green herb can be harvested by means of sickle from 2-3 cm above the ground. After wilting for 6-10 hrs, fresh herb is used for distillation which contains 0.5 to 0.68 % of essential oil. The wilted crop is cut 10 cm above the ground by means of a sickle on bright sunny days, since harvesting on cloudy or rainy days decrease the menthol content in the oil. Under good management conditions, the crop gives desirable economic yield for about four years. Harvesting is also done for direct leaf marketing in culinary use.

Yield

An average of 30-50 tonnes of herbage per hectare in 2 harvests in a year produces 150-250 kg of oil per hectare in a year. The fresh herb contains 0.4% oil. The oil, golden-yellow in colour, is a mobile liquid, contains 70-80% menthol. The oil is dried of adhering moisture and stored in aluminium or steel containers. These containers filled up to the brim and stored in a dry cool godown. The wilted crop is cut 10 cm above the ground by means of a sickle on bright sunny days, since harvesting on cloudy or rainy days decrease the menthol content in the oil. The average fresh herbage yield is 20 tonnes per hectare in two harvests.

Post-harvest management

Before distillation, temporary storage of mint herbage is required after it is shade dried for about 24 hours. Turning is required to avoid initiation of decomposition of the herbage during pre-distillation drying process. There may be some reduction in oil yield if wilted herbage crop stored for of 2-3 days.

Distillation for essential oil

The herbage contains 0.5-0.8% essential oil which is obtained through steam distillation. About 80% of the oil is received in the receiver in about one hour. Oil can also be obtained by distilling dry herb. The distillation is done both in primitive (Clevenger apparatus) and modern stills. In the former, the principle of water and steam-distillation is followed. While in the later, steam generated in a separate boiler is employed. Mint oil is light and golden in colour and it should be completely free from moisture before storage. It can be stored in huge steel, galvanized steel, or aluminium containers that are filled to the brim to prevent air from staying within for vacuum packing. Well packed containers should be placed in a cool dark place and low humidity.

Activities

Visit a nearby oil yielding spices field.

Material required: Pen, Pencil and notebook etc.

Procedure: Write the following observation during visit

- Name of the crop & variety
- Spacing adopt
- Approximate height of plant
- Date of sowing, time of flowering, fruiting and harvesting.

Check Your Progress

A. Fill in the blank

1. Ocimum belongs to the family of……
2. Ocimum is propagated through……
3. Shivalik is a variety of……
4. The seedling of ocimum is ready for transplanting……
5. Mint is propagated through ……

B. Multiple choice question

1. Vikarsudha is a variety of _____

(a) Mint

(b) Ocimum

(c) Thymes

(d) None of these

2. Planting time of ocimum is_____

(a) Kharif season

(b) Rabi season

(c) Summer season

(d) Multi season

3. The centre of origin of Mint is _____.

(a) Mediterranean
(b) Russia
(c) S. Africa
(d) None of these

4. The fresh mint contains _____% oil.

(a) 0.8
(b) 0.6
(c) 0.4
(d) 1.0

C. Subjective Questions

1. What is 'Clevenger apparatus' and used for, describe?
2. What are the varieties of Japanese mint?
3. How Bergamot mint differ from Japanese mint, Peppermint and Spearmint?
4. What is the chemical composition of Spearmint?
5. What are the uses of mint oil?

Module 4
Seed Spice Crops Cultivation

Module Overview

Seed spices are the crops having seed as main economical part. They are used in whole or value-added form for imparting flavour aroma and pungency to food. Other than culinary, they are widely used in pharma and other industries for carminative and preservative purposes.

Seed spices are an important spices crop and they are mainly concentrated in arid and semi-arid parts of India as result of diverse Agro climatic conditions. India produces more than 20 seed spices. Cumin, Coriander, Dill seeds, Fenugreek and Fennel are the major seed spices cultivated in the country. Different states are renowned for different spices but more than 80 percent of the world's seed spices are grown in Rajasthan and Gujarat.

Learning Outcomes

After completing this module, you will be able to:

- Cultivate seed spices effectively by understanding their growth requirements, selecting appropriate varieties, and applying proper planting, irrigation, and harvesting techniques.
- Demonstrate application of manures, bio-fertilizers, and fertilizers effectively to enhance soil fertility.

Module Structure

- Session 1: Cultivate Seed Spices
- Session 2: Soil Sampling
- Session 3: Application Of Manures, Bio Fertilizers and Fertilizers

Session 1: Cultivate Seed Spices

Coriander (*Coriandrum sativum)*

Introduction

Coriander is seed spice crop and a member of family “Apiaceae”. Both green leaves and grain are given by coriander plant which are used primarily for culinary purposes. Coriander serves as an important ingredient in food flavourings, meat products, bakery products, puddings, soda and syrups, candy,

preserves, and liquors. Solvent extracted oleoresin or steam-distilled essential oil are prepared from coriander seeds. Coriander founds it centre of origin in east and Mediterranean region. Presently, it is mainly grown in India, Morocco, Romania, Argentina, Russia, Spain, Yugoslavia, France, Italy, Holland (presently Netherlands), Burma (presently Myanmar), Pakistan, Turkey, Mexico Canada, and Bulgaria and to some extent in England, Canada and USA.

Fig. 4.1: Coriader Field

Fig. 4.2: Coriander Flower

Fig. 4.3: Coriander seed

State-wise recommended varieties

Name of State	Important Varieties
Andhra Pradesh	Swathi, Sindhu, Lam Selection CS 2 and Sadhna
Bihar	Rajendra Swathi and Rajendra Sonia
Haryana	Hisar Sugandh, Hisar Anand and Hisar Surabhi
Gujarat	Gujarat Coriander -1 (GCr-1), Gujarat Coriander- 2 (GCr-2) and Gujarat Coriander-3 (GCr-3)
Rajasthan	Ajmer Coriander-1 (ACr-1), Ajmer Coriander-2 (ACr-2), Ajmer Coriander-3 (ACr-3), Ajmer Green Coriander-1 (AGCr-1), Rajasthan Coriander-41 (RCr-41), Rajasthan Coriander-20 (RCr-20), Rajasthan Coriander-435 (RCr-435)
Uttar Pradesh	Pant Haritma
Tamil Nadu	Co-1, Co-2, Co-3 and CS-287

Climate and Soil

Coriander is a tropical crop and can be grown throughout the year (except very hot season *i.e.,* March-May) for leaf purpose. For seed purpose, a dry and cold weather free from frost, especially during flowering and fruit setting stage, is required. Germination of coriander is severely reduced at temperature above 30°C and below 10°C. Heavy rains are harmful for the crop and continuous cloudy weather invites diseases and pest. The coriander can be grown in any type of soil suitable for cultivation. It is cultivated both as irrigated and un-irrigated crop. As an irrigated crop, it can be cultivated in almost all type of soils having sufficient organic matter but dry land crop may be taken only on heavy soils having good water retention capacity. Soil pH should be near 7.0 for better growth and quality produce of coriander. Saline, alkaline and sandy soils are not suitable for its cultivation.

Land preparation

It can be grown in any type of soil suitable for cultivation. If irrigation facilities are available, then it can be cultivated in almost all type of soils which are rich organic matter. Cultivation of coriander, as a rainfed crop, can also be taken for soils which have good water retention capacity. For successful cultivation of coriander, it is better to have soil pH near to 7.0. The land should be fine tilth for 3-4 times in order to prepare it for cultivating coriander. Planking should be done immediately after ploughing so to check the moisture loss. Pre-sowing irrigation is required if there is insufficient moisture in soil before land preparation under irrigated conditions. In order to conserve moisture, plough field after every rainfall for ensuring dry-land coriander cultivation. It is necessary that field must be kept either fallow or short duration crop like green gram or black gram should be grown and harvested as early as possible. At the time of sowing, soil must be friable to obtain better seed bed for better seedling emergence and their further establishment and growth.

Sowing time

Sowing of coriander may be done at any time of the year when suitable temperature and moisture is available. Sowing of coriander for grain purpose should be done between 15th Oct to15th Nov for *Rabi* season in north and western Indian conditions. Sowing of coriander should be done when the temperature has come down to a level which does not affect the germination adversely. Early sowing is better for getting higher yield but prevailing high temperature at sowing time reduces the plant stand. Earlier sown crop, under north Indian condition, come to flowering stage at the earliest which makes them more vulnerable to frost damage.

In Malwa region of Madhya Pradesh, *Kharif* crop is normally sown during August-September and in June-July under Coimbatore conditions of Tamil Nadu but the *Rabi* crop gives better seed yield than the *Kharif* crop.

For getting an early-seed crop in southern areas, sowing should be done in mid-May and harvesting in June-July. The coriander can be sown at any time if it is grown for leaves except during the year when temperature is too high (April to June).

Seed rate and method of sowing

As a sole crop, seed rate should be 10 to 15 kg/ha and as an intercrop, 5-6 kg/ha seed should be used. Coriander seeds should be trampled or crushed into halves with feet or by rubbing with hands and then sowing of seed should be done. Afterward seeds are treated with fungicide Agrosan GN or any other mercurial fungicide at the rate of 2.0 g/kg of seed.

Sowing is done in 25-30 cm apart rows either by seed drill or by broadcasting. Normally, coriander is sown by broadcasting and line sowing methods. Under high fertility situation with irrigation, the row distance should be kept 30 - 40 cm and seed depth should not exceed 4.0 - 5.0 cm. In broadcasting method, seed should be mixed in the soil with the help of rakes in such a way that all seeds are covered well with the sand. In order to hasten germination sometimes seeds should be soaked in water for 12-14 hours and excess moisture is drained out by spreading seeds over cloth or gunny bags under shade, and then sown in the field. Soaking coriander in warm water, 10 ppm IAA, 20 ppm NAA or 50 ppm GA increased germination percentage and yield.

Manures and Fertilizers

Soil is the most important source of plant nutrients and it loses its nutrients in different ways. Crop harvesting and weeds remove large quantities of nutrients from the soil. Leaching and soil erosion is responsible for removal of nutrients from soil. Volatilization and denitrification are also one of the important sources of nitrogen loss. In the situation, where there is a higher requirement of nutrients than what the soil can supplied, there is need to apply nutrients as manures and fertilizers. Application of manure and fertilizers should be done based on soil testing report. The organic manure should be applied three weeks before sowing of the crop. At the time of last ploughing, basal application of manures and fertilizer should be done. In order to get higher nutrient use efficiency, it is better to apply full dose of P_2O_5 and K_2O and $1/3^{rd}$ N should be applied as basal dose at the time of last ploughing and remaining $2/3^{rd}$ N should be applied in two equal split doses as top dressing at 30 and 60 days after sowing. Generally,

farmers, in spite of additional requirement of nutrients, are not used to apply manure for coriander cultivation. Therefore, it is necessary to apply 10 to 15 tonnes of well-rotted FYM and 20 kg of Nitrogen, 30 kg of phosphoric acid and 20 kg of potash per hectare in the form of fertilizer. In irrigated area, the quantity of nitrogen dose should be increased up to 50 kg per hectare.

Irrigation

Irrigation also plays important role in crop protection against incidence of frost. Depending upon temperature and soil type, 3-6 irrigations are needed for successful cultivation of coriander. It is necessary to apply irrigation at critical stages *viz*. seedling stage (30-40 DAS), grand growth period (50-60 DAS), flowering (70-80 DAS) and seed formation stage (90-100 DAS). If sowing of coriander is done by broadcasting methods, then the first irrigation should be given immediately after broadcasting and subsequent second light irrigation should be given 8-10 days after first irrigation to facilitate germination of seeds and after establishment of crop the subsequent irrigations should be given according to the requirement of the crop.

Crop rotation

Crop rotation is an important agro technique which provides soil sustainability with higher productivity of quality produce. Under intensive cultivation, a kharif crop of short-duration i.e. pulse or vegetable crop should be grown. Under rainfed condition, it is grown as a pure crop in rotation with cotton or millets and as a mixed crop, it can be grown along with cotton or black gram. In the Northern part of our country, coriander is successfully grown as a companion crop with sugarcane. With proper crop rotation, the influence of insect-pests, diseases and weeds are also reduced. Some important crop rotations suggested are:

- Maize-Potato-Coriander
- Summer moong- Bajra- Coriander
- Rice- Coriander- Summer moong/ fallow
- Green gram/Black gram – Coriander-Okra
- Cowpea-Coriander- Okra
- Cluster Bean-Coriander–Summer maize.

Weed management

The crop growth is reduced by incidence of weed by two main mechanisms. First mechanism which involves competition for resources such as space, light, moisture, nutrients, air, etc. and second mechanism of causing loss in crop production is allopathic effect which involves the releasing of toxins into the environment. In *Rabi* season, weed problem is more during coriander cultivation under irrigated condition. The important weed flora of coriander is: Piyaji, Sanji, Bathua, and Krishan neel. The crop slowly grows taking up to 40-45 DAS. Therefore, crop need to be kept weed free up to 50 DAS. Two to three hand weeding and hoeing are necessary for effective management of weeds. In order to ensure effective weed management, it is necessary for weeding followed by hoeing at 30 and 60 days after sowing. Weed control in coriander should be done by pre-plant incorporation of Fluchloralin @ 0.75 to 1.0 kg/ha or per-emergence application of Oxyflurofen @ 0.15 kg/ha or Pendimethalin @ 0.75 to 1.0 kg/ha, after dissolving in 400-500 litres of water, is recommended. In order to ensure cost effective weed management, it is necessary to follow one had weeding at 50-55 DAS after chemical weed control. Summer ploughing is also recommended for alleviating the weed problem in coriander. In the situation of intercropping, weed control measures should be taken keeping in view both the crops.

Management of Abiotic stress

Under north Indian situation mainly in Rajasthan, Haryana, Punjab and Madhya Pradesh, in unirrigated areas, crop damage by abiotic stress is very frequent. It is advisable to apply irrigation as soon as the expectation of frost increases, it will help to save crop from frost. Fumigation of the crop is the effective method of control of crop from frost. Farmer can also protect crops by burning of waste materials on the bunds of field in night is useful in protecting the crop during the frost prone period. It is advisable to apply 0.1% sulphuric acid at flowering stage for protection of the crop from frost.

Pests and Diseases

Insects-Pests

Coriander aphid, *Hyadaphis coriandri* (Das)

The coriander aphid, *H. coriandri, is* recorded in all major growing areas of India. They are most abundant on coriander crop during winter season particularly from December to March. On coriander plant, aphids colonize on leaves, tender apical shoots and umbels where both nymphs and adults suck cell sap and devitalize the plant. Infestation in early stages causes distortion in plant growth, yellowing of leaves and reducing their vigour. The heavy infestation of aphid on

coriander are occurred between December to March and cause the loss of more than 50% of yield in unprotected crop.

Thrips

Thrips are tiny insects. It is also one of pests of coriander crop. Amongst the species of thrips attacking seed spices, *Thrips tabaci* is the major specie found on most of the seed spice crops. Both nymphs and adults' feeds on umbel, leaf sheath and stems of plants. Both nymphs and adults congregate in between the leaf sheath and stems of plants which results in drying of the leaves. Severe infestation results in drying of flowers and production of shrivelled fruits.

Mite

Among the other sucking pests, the tetranychidae mite *Petrobialatens* is another serious pest on coriander and cumin. It is found infesting in semi-arid and arid region of Rajasthan. *P. lateens* have also been reported on coriander crop in southern part of India. The brown wheat mite, *Petrobialatens* was first reported feeding on coriander. It remains active during winter with peak activity in March. It is a minute, non-webbing and swift moving mite and has a tendency to dislodge from the plant when disturbed.

Management strategies of Aphids/Thrips/Mites:

- Use botanicals Neem seed kernel extract (NSKE) 5.0%, Neem oil 2.0%, Azadirachtin 10000 ppm @ 2.0ml/lire and bio-pesticides like *Verticillium lacanii* 1*108 CFU's/gm 5.0 g. /litre of water as foliar spray on the crops.
- For mite control, use bio pesticide *Hirsutells thompsoni* comprising $1x10^8$ CFU's/g @ 5.0 g/litre of water as foliar spray on the crops.
- There is no level claim of any insecticides in coriander crop. However, in case of severe infestation, need based use of chemical insecticides i.e., Emamectin benzoate @ 10 g a.i./ha or Thiacloprid @ 0.24% or Dimethoate 30EC @ 0.03% to prevent losses.

Diseases

Powdery mildew

This is one of the important diseases of coriander, which generally appears in all coriander growing areas. The disease is caused by *Erysiphe polygoni*. The disease symptoms appear as a white powdery mass on the leaves and twigs of the plants in initial stage and later on whole plant is covered with whitish powder. It generally appears in the month of February March and causes significant loss to the crop yield.

Management strategies:

- Early sowing of coriander is effective for management of powdery mildew.
- Application of sulphur dust @ 25kg/ha or spray with Wettable Sulphur suspension (0.1%) is also effective against powdery mildew control in coriander. The spray should be repeated at 10-15 days' interval if required.
- Seed treatment with Thiram proved effective in reducing severity of the disease and increased the seed.

Wilt (*Fusarium oxysporiurn f. sp. coriandri)*

Younger plants are more susceptible to wilt. Yellowing as well as drooping of leaves and terminal branches are symptoms of disease. The infected plant dries up due to wilting in later stage.

Management strategies:

- The pathogen is coriander specific, thus it is necessary to follow crop rotation for disease management.
- Solarization of soil during summer, use of disease free seed, seed treatment with Captan or Thiram @ 3.0g/ kg of seed should also be followed.
- Seed treatment with Trichoderma viridae @ 4g/kg seed is also effective in reducing wilt incidence in coriander.

Stem gall (*Protomycesma crosporus*)

The symptoms appear as galls (small tumour) on the stem, leaf stalk and peduncles. The seeds are deformed and the yield is reduced.

Management strategies:

- Seed treatment with Captafol 2g/ kg seed is effective in inhibiting seed borne infection with the disease.
- Spraying 0.1% Carbendazim or Captan 0.2%, 2-3 times at an interval of 10-15 days.
- Soil solarization and use of resistant varieties are effective for the management of disease.

Harvesting and Yield

Normally, coriander gets mature in 100-150 days after sowing and duration of maturity varies with type of variety used and climate of the location in where it is grown. Crop grown during *Kharif* matures earlier due to high temperature than *Rabi* season. When the grain changes it colour to straw or light brown colour,

harvesting should be done. The plants are cut or pulled and filled into small stocks in the field to wither for two or three days. Threshing should be done by seed spice threshers which saves time, labour and gives quality produce. To minimise the moisture content, the produce may be dried in open bright sunlight. Cabinet solar dryer is the best option for quick & safe drying. The moisture should be below 6 per cent for safe storage. In order to get the quality produce, it is necessary to harvest when seeds are green and have attained full size. For getting green seed, the crop should be dried under shade for retaining the green colour. In order to avoid losses due to shattering and splitting, harvesting should be done timely. With the normal cultivation practices, under irrigated condition, an average yield of 10 to 15 q/ha can be obtained and under rainfed cultivation, average yield of 4 to 5 q/ha can be obtained. With the adoption of recommended scientific cultivation practices, yield up to 20 q/ha under unirrigated and up to 25 q/ha in irrigated conditions can be obtained.

Processing and post-harvesting management

The fresh greens, which consists of edible portions, are the tender leaves and stem which are cut to length of about 5-7 cm above ground. The yellow diseased and damaged leaves are trimmed off and weed plants and straw is culled during cleaning and dressing. Healthy and disease free leaves are tied into small bunches for the convenience in handling, transportation and marketing. The leaves of coriander are sun dried or dehydrated in a suitable dehydrator, for further use in off-season.

Storage: The fresh coriander leaves are highly perishable and deteriorates rapidly at temperature above 5°C. Therefore, the fresh leaves bunch should be marketed soon after harvesting. The leaves can be sorted only for about 24-36 hours after harvesting under ambient condition. However, in cold store at 0°C temperature and 90% relative humidity, the storage period can be extended for one week. Harvested plants are dried in the sunlight for 1-2 days to bring the moisture level down to 18%. The dried plant is then trashed to remove the seeds. Coriander seed is mainly processed into powder by crushing and the powder which enjoy an aroma, is used as food ingredient. Seeds which contain 0.1-1.5% of oil are used to extract essential oils.

Cumin (*Cuminum cyminum* L.)

Cumin (*Cuminum cyminum L.*) is an annual herb belonging Apiaceae family and possessing the somatic chromosome number of 2n=14. It is one the earliest known minor spices used by human being. The cuminum is the Latin name which was derived from the Greek word “Kuminon”, originated from the old

Babyleniun ka-ma-nu'. The native place of cumin is Egypt, grown in most the hot regions like India, North Africa, China and America.

Zira is the most common Indian name of cumin and besides this there are many other popular regional names. In Tamil it is known as *Jiragam* and in Telgu as *Jilakara*. People all over the world used cumin extensively as seed spices and it is second most popular spice after black pepper. Southern Mediterranean area, to the deserts of Egypt and other Arabian countries, are native place of the cumin. The plant is cultivated in many parts around the world. It is grown widely in China, India, Indonesia, Iran, Japan, Morocco, Southern Russia, Syria and Turkey. In Ethiopia, fruits are offered for sale on almost every market and small-scale cultivation is widespread. Cumin is produced chiefly in India. The two states of semi-arid region of India *viz*. Rajasthan and Gujarat together contribute approximately 90 per cent of the production of our country. In Rajasthan, cumin is mainly grown in Jodhpur division and the major districts producing cumin are Jalore, Barmer, Jodhpur, Nagour and Pali, Ajmer and Bhilwara. Cumin seeds are believed to be good for digestive and related problems and a medicine for preventing cancer.

Fig. 4.5: Cumin flower

Fig. 4.4: Cumin seed

Important Varieties

Number of good varieties, suitable for different agro climate region, are available for cultivation of cumin. The suitability of variety for a region depends on its adaptation on the soil and climatic conditions. The important varieties of cumin are as below:

Name of State	Important Varieties
Gujarat	GC-1, GC-2, GC-3, GC-4 and GC-5
Rajasthan	RZ-19, RZ-209, RZ-223, RZ-341 and RZ-345

Land preparation

Cumin can be grown in wide range of soil, however sandy loam to medium heavy soils containing sufficient organic matter is most suitable. Suitable provision for drainage of excessive water should be made as stagnated water and excessive moisture is very harmful for cultivation of cumin. The land should be well prepared for better germination of seeds and growth of plant. In order to develop fine soil tilth, it is necessary to do first ploughing with soil turning plough followed by 2-3 ploughing with harrow. In order to ensure better germination of seed, it is necessary that, at the time of sowing, there should be good moisture in the soil. To ensure the moisture, planking should be done after every ploughing operation.

Cropping system

Cumin is not suitable for growing as mixed or intercrop. However, the rotation crops required being grown should be based organic farming methods. In order to manage certain soil borne disease, it is necessary to follow crop rotation involving different crop in some season in succeeding year.

Suitable and efficient cropping systems for cumin growing areas are as below:

- Dhaincha - Cumin
- Dhaincha - Cumin-Green gram
- Maize - Cumin - Summer Moong
- Pearl Millet- Cumin

Crop rotation

In order to control wilt disease, continuous cumin cropping in the same field should be avoided. It is advisable to provide at least three years' rotation with other crops to minimize wilt disease in affected fields. Growing of more water requiring crops like wheat, castor, mustard, isabgol, lucerne etc. should be avoided as it increases the incidence of blight in cumin. Mustard, being an alternate host of Alternaria blight, should not be grown in the vicinity of cumin.

Sowing time

Time of sowing is an important non-monitory input that involve no cost but decide the level of production, disease, and pest incidence. Sowing of cumin should be done at appropriate time so that that critical period of flowering escape the period of higher humidity and in turn protects the crop from incidence of diseases and pests. For better germination, the appropriate temperature should be below 30^0C. The appropriate time of sowing of cumin is mid-November to first week of December. The crops, sown in month of November, have higher occurrence of cumin blight than those sown in December-January. This is due to coincidence of flowering stage of cumin in the period of low temperature and high humidity. The crops, which were sown in the second week of December, had least infestation. In order to improve germination, treat the seeds with fungicide.

Seed rate

Optimum plant population is necessary for realizing higher yield of cumin with the use appropriate seed rate. Depending on variety and method of sowing, the optimum seed rate for cumin is 12 to 15 kg per hectare. Cumin should be sown either in lines or by the broadcasting method. With help of iron teeth rakes, seeds should be covered lightly by soil. For facilitating intercultural operation, 30 cm row to row spacing is better than broadcasting. In order to ensure optimum plant spacing, it is necessary that seeds should be drilled at a spacing of 15 cm along the line. In order to facilitate germination in time, it is necessary to take care that the seeds should not go deep inside the soil while being covered with soil.

Seed Treatment

The germination of cumin seed takes 10-12 days. Hence, in order to hasten germination, it is necessary that seed should be soaked in water for eight hours and then seed should be surface dried under shade for getting fast and better germination. The seed treatment, for enhancement of germination saves one irrigation. It has been found that pre-sprouted seeds results good germination within six days and require only one irrigation immediately after sowing. To control seed borne diseases, it is necessary that seed should be treated with ceresan or thiram or bavistin @ 2.5 g/kg seed. Application of Trichoderma @ 8-10 gm per kg seed is beneficial to control fungal disease. Combination of seed treatment and spray with bavistin or benlate were effective in reducing the disease.

Manure and Fertilizers

The requirement of manure and fertilizer for cumin is based on the fertility status of the soil. Hence, application of manure and fertilizer should be done based on soil testing report. Applying manures and fertilizers judiciously is an important aspect with respect to plant growth, seed development, yield and quality of produce. The crop responds well to fertilizer application. Therefore, in addition to FYM, apply 15 kg N, 20kg P_2O_5 and K_2O per hectares as basal dose and remaining 30 kg should be applied after 60 days of sowing as top dressing.

Irrigation

Immediately after sowing, light irrigation should be applied followed by other light irrigation after 8-10 days. The first irrigation should be kept light otherwise it results in the uneven distribution of seeds. Third irrigation may also be applied after another 4-5 days to allow complete germination if the day temperature is high. Afterward, depending on the weather conditions and type of soil, the irrigation should be provided at an interval of 20-30 days for better and fast growth of plants. At the time of grain formation, moisture requirement is higher. Hence, the last irrigation should be high enough to supplement the moisture requirement during the crop ripening stage.

Weed management

Weed is a serious problem in cumin crop because initial growth of cumin is very slow. Weed exert severe competition with the cumin crop for nutrients and moisture. 30-40 days after sowing is the critical period for first weeding and hoeing for proper growth of crop. It is necessary to do thinning in order to keep plant to plant distance to 10-15 cm within the rows. In the situation of appearance of second flush of weeds, another 1-2 hoeing's and weeding's may also be done for better growth of cumin. Hoeing also helps in breaking crust. In cumin, weeding should be done at 15 and 30 DAS. The common weeds in cumin are Zeeri, Bathua Piaji, Pilisanjee. The seed of Zeeri weed very much resembles to cumin. Hence, it is a serious type of weed for cumin. The contamination of cumin seed with Zeeri seed fetches poor prices in the market. This weed should be removed at the flowering stage, so as to get higher yield and good quality seeds.

Pests and Diseases

Insect-Pests

Aphid (*Aphids gossypii* and *Myzus persicae*): Aphids are the most damaging insect pest of cumin. Population build-up of aphids on cumin starts at vegetative stage and peaks at flowering to seed formation stages. It is found in colonies

sometimes very serious in patches on tender leaves, stem and inflorescence. Both nymphs and adults suck sap from the tender leaves thus reducing market value of the product. The severe infestation affects the yield and quality of leaves badly.

Control:

- Yellow colours sticky traps have been used in minimizing the aphid population.
- Cumin sown up to the first week of November has low infestation than the crop sown after this date. Higher yield can also be obtained in early sown crop.
- Spraying of Neem Seed Kernel Extract (NSKE) @ 5 % or Neem oil 2% effectively cheek the early population build-up of aphids on the crop.
- At high aphid population, any one of the synthetic insecticides should he sprayed - Dimethoate @ 0.03%, Metasytox @ 0.03%, Emamectin benzoate @ 10 g a.i./ha or Imidacloprid - 0.005%.

Thrip (*Thrips tabaci*): Infestation of thrips started at early vegetative growth of crop and found up to flowering stages. They suck the plant leaves and cause yellowing and drying of leaves. Higher population resulted drying of whole plants.

Control

- Spraying of Neem Seed Kernel Extract (NSKE) at 5% or neem oil at 2% or Dimethoate @ 0.03% or Metasystox @ 0.03% or Thiomethoxam @ 0.025% controls pest effectively.

Diseases

Blight: The infected plants show dark brown blight appearance on the leaves and stem resulting in withering off the affected plants.

Management

- The disease can be controlled by spray application of Mancozeb (0.2%) or Difenoconazole (0.05%) or Azoxystrobin (0.1%) at the time of appearance of disease symptoms.
- Spray scheduling of Mancozeb at 45-60 days of sowing followed by 2-3 spray of Difenoconazole or Azoxystrobin at 15 days' interval effectively manage the disease.

Wilt: The infected plants exhibit drooping of leaves and later epinasty which leads to death of the plant. The wilt infection may occur in patches at any stage

of crop growth. After occurrence of the wilt in cumin, it becomes very difficult to reduce the damage.

Management

- Summer ploughing should be done.
- Crop rotation of at least three years should be followed with non-host crops.
- Healthy and disease free seed should be procured for sowing.
- Before sowing seed, it should be treated with appropriate/recommended fungicides or Trichoderma.
- Seed treatment (10g/kg) and soil application (2.5 kg/ha mixed with 50 kg FYM) with microbial consortia.

Powdery mildew: White powdery mass appears on the leaves and twigs of the plant in the initial stages. Later on, whole plant is covered with this whitish powder.

Management

- The powdery mildew in cumin may be controlled by dusting of Sulphur @ 20-25 kg/ha or spraying Wettable Sulphur @ 0.2 % at 15 days' interval starting from initiation of disease.

Harvesting and Yield

Cumin crop takes near about 90-120 days to reach maturity. This is ideal stage for harvesting of cumin for quality and quantity. It has been found that physiological maturity (complete yellowing of plant) is the best stage for harvesting of the crop to get good quality high yield of cumin. The quality parameters of cumin get deteriorate if delay in harvesting (complete drying of plants) of cumin. Sun drying, for longer time, of harvested material before threshing reduced quality of cumin in which volatile oil content of cumin seeds are also lost. In order to avoid shattering losses of seeds as well as yield, the cumin crop should be harvested in early morning. The crop should be beaten and trampled on a clean threshing floor to get good quality of seeds but, on large scale cultivation, threshing can also be done by thresher. With the adoption of improved scientific cultivation practices, the average yield of cumin is 8-10 quintal/hectare.

Processing and post-harvesting management

The cumin seeds are dried in partial shade in the sun and the moisture content of seed should be kept to 9 per cent. High seed moisture content may lead to chances of storage contamination by fungus. The dried, cleaned, graded produce

is packed in the standard sized packs/containers and appropriately labelled. The dried seed is filled in gunny bags lined with degradable environment friendly plastic film. Each bag is sealed and stored under clean, dry and ventilated place. Care should be taken to maintain the vital quality of an organic ingredient throughout each step of its processing. The mature dried seeds are distilled to obtain the essential oil. Hydro or steam distillation method is generally used for extraction of essential oil. The dried seeds are crushed or as such steam distilled to yield 2.5 to 4.5% of valuable volatile oil depending upon variety and location. The oleoresin from cumin has good demand in the international market. The processed products include cumin essential oil, cumin powder, cumin oleoresin and fixed oil.

Fennel *(Foeniculum Vulgare* Mill.)

Fennel comes in Apiaceae family and it is native of Mediterranean and Southern European region and is one of popular major seed spice in India mainly grown in Rabi season. In due course of time, it gets spread to the far East and far north in Europe. Fennel has been symbol of success for Roman. During the thirteenth century, fennel was considered as a royal spice in England and it used to be served to kings with fruits. The most common Indian name is *Saunf* and there are many popular regional names. Major fennel growing countries are Russia, Romania, France, Germany, Italy, India, Argentina and USA. Rajasthan and Gujarat are major fennel producing states in India. In Rajasthan, it is mainly cultivated in Tonk, Sirohi, Jodhpur, Ajmer, Udaipur and Pali and in Gujarat the major fennel growing area are Khera, Mehasana, Banaskantha, Baroda, and Ahmedabad.

Fig. 4.7: Fennel flower

Fig. 4.6: Fennel seed

Major fennel growing district with higher region in India are given in table.

State-wise recommended varieties

Name of State	Important Varieties
Haryana	Hisar Swarup
Gujarat	PF-35, Gujarat Fennel-1, Gujarat Fennel-2, Gujarat Fennel-11, Gujarat Fennel-12 and Fennel-S, 7-9
Rajasthan	Ajmer Fennel-1 (AF-1), Ajmer Fennel-2 (AF-2), Ajmer Fennel-3 (AF-3), RF-101, RF-125, RF-143,
Tamil Nadu	Co-1

Land preparation

It can be successfully cultivated on all types of soil except sandy soil. It easily thrives on loamy soil which has proper drainage and rich in plant nutrients and lime. Heavy soils, comprising higher organic matter with better water holding capacity, are more desirable than light soils. It does not grow well in acidic soil. It mostly prefers neutral to slightly alkaline soil having the pH range 6.5-8.0. Avoid saline soil, as low level of salinity significantly reduce seed yield. Large amount of Na is removed by Stover of fennel which indicate the capacity of fennel plant to tolerate moderate level of sodicity. Fennel can also be grown in polluted soil because it is low accumulator of heavy metals. Fennel can also be easily grown in soils having problem of root knot nematode because it is poor host of root knot nematodes.

Cropping system

Adoption of proper cropping system is the best way to enhance resource use efficiency of land, water and nutrients. In the present scenario of resource crisis, it is better to focus on system productivity rather than resource productivity for realising higher resource use efficiency. Because of its initial slow growth for 60-80 days, fennel is an ideal seed spice crop suited for inclusion of other short duration component crops. Therefore, some short duration vegetable crops like carrot, garlic, onion, French radish, French bean, knol-khol, chillies, etc. may successfully be taken along with fennel.

Crop rotation: Proper crop rotation should be followed for taking care of different types of soil borne disease in fennel. The suitable crop rotations suggested for different fennel growing area is shown below:

Gujarat/Rajasthan

The important crop rotation is as below:

Green gram – Fennel- Summer fallow

Black gram - Fennel- Summer fallow

Cowpea – Fennel-Summer fallow

Cluster bean- Fennel- Summer fallow

Punjab

The important crop rotation is as below:

Paddy - Fennel

Maize - Fennel

Moong - Fennel

Kharif fodder- Fennel

Green gram/ black gram- Fennel

Cluster bean/ cowpea- Fennel

Sowing time

Fennel is sown in the month of October to first fortnight of November. However, under North Indian condition, it can be sown in the hills during March - April. Sowing of fennel, in October, is an ideal period for main season crop. Transplanting method in fennel is highly successful for getting higher yield so that nursery should be prepared in the month of June or July. The seedlings of 45-60 days should be transplanted in the main field in the month of August.

Seed Rate

Maintenance of proper plant population is the pre-requisite for getting optimum yield of fennel. Therefore, optimum seed rate of fennel depend upon the method of sowing and type of variety used. Size of seed and pattern of branching determine the seed rate. Seed rate of smaller seeded varieties is comparatively lower than bold seeded variety with less branching habit. Generally, 2.5-3.0 kg/ha seed is required for sowing by transplanting method and 10-12 kg/ha for direct sown fennel.

Seed treatment

In order to control seed borne and soil borne disease, seed should be treated with Bavistin or Captan or Thiram @ 2.5 g/kg seed. Seed should also be treated with Trichoderma @ 4g/kg seed especially for organic fennel production.

Raising seedling in nursery

Sowing of seeds is done during the month of May – June in nursery beds. Seedlings of 1.5 or 2 months age are suitable for transplanting in the main field in the month during August-September. Seedlings are transplanted in rows with row-to-row spacing about 60-80 cm or even up to 1 meter and maintain 40-80 cm spacing between plants within the row. Nursery beds of 3.0 x 0.5 m size are prepared; seeds are broadcasted by 15th June for *Kharif* fennel while by 15th August for *Rabi* fennel. For raising seedling in nursery land should be fertile having good drainage. Raised bed of 1 meter width and of suitable length must be prepared during May - June and sowing of about 2.5 - 3.0 kg seed is done, in first week of September, in a nursery area of 1000 m^2 for raising seedlings for one hectare. Seeds are broadcasted in a well-prepared seedbed. Nursery bed should be protected against the high temperature and strong sunlight by covering with straw or stalk-mulch and should be irrigated. The seeds take 7-days for germination and straw mulch should be removed after germination. As per requirement, irrigation must be given. Weeds should be removed manually from nursery. The seedlings become ready for transplanting after 45-50 days.

Sowing methods

In fennel, sowing is normally done by two methods *viz.* direct sowing and transplanting method depending upon the variety used and availability of field.

Direct sowing

In direct method of sowing, fennel is sown either in lines or by broadcasting in a well-prepared flat seedbed and raking the bed surface prudently for mixing the same in upper 1-2 cm surface area. Compared to broadcasting method, sowing of fennel in lines is much better since it facilitates inter cultural operations like hoeing and weeding. Soil type, type of seeds and soil moisture at the time of sowing determine the depth of sowing. Fennel seeds, which are to be sown, are of small size in nature. Hence, they should be sown at a depth of 1.5-2.0 cm because deeper sowing delays germination. Depending upon the temperature, fennel takes 7-8 days for germination. Sowing should be done in rows which are

45-60 cm apart with plant-to-plant distance of 20 cm. In some areas broadcasting method is adopted when it is taken as mixed crop with chilies or any cole crops. In the broadcasting method, seed are broadcasted in the beds.

Transplanting

Fennel is a longer duration seed spice crop, hence in Gujarat and Rajasthan, fennel is grown by transplanting method. After providing irrigation, seedling of 45-50 days old should be removed carefully from nursery. Light irrigation must be provided, after transplanting, for establishment of seedling. In order to protect against high temperature and strong sunlight, nursery beds should be covered with straw mulch followed by constant supply of moisture.

Manures and Fertilizers

Nutritional requirement of any crop varies from region to region depending upon type and fertility status of the soil, targeted yield of crop and variety to be grown. Manure and fertilizer should be applied as per recommendation of soil testing report of fennel as well as targeted yield of fennel. Well decomposed FYM @ 10-15.0 ton per hectare should be applied at least 3-4 weeks before sowing for getting better production of fennel. In addition to this apply 90 kg N and 40 kg P_2O_5 per hectare. It has been found that fennel give positive yield up to 120 kg N and 50 kg P_2O_5 per hectare. Apply 1/3rd of total N and full dose of P_2O_5 as basal dose at the time of sowing and balance N should be applied in two equal splits as top dressing at 30 and 60 days after sowing in the standing crop. The biofertilizer, *Azospirillum*, applied both as seed inoculation (500 g/ha) and soil application (2.5 kg /ha) along with application of 10 tonnes well rotten FYM proved best and produced highest fennel yield. In Fennel cv. PF-35, foliar spray of micro-nutrients like Zn and B is also recommended for higher production and profit. Zn (0.6%) in form of $ZnSO_4$ plus lime (0.3%) prepared and mixed with B (0.2%) in the form of borax solution should be applied as foliar spray along with top dressing of nitrogen.

Irrigation

Fennel requires more irrigations than other seed spices. In fennel, 6-7 irrigation should be applied at an interval of 15-20 days in early stages and 12-15 days in March-April. Under dry condition, in direct seeded fennel, first light irrigation should be given immediately after sowing and second light irrigation should be given after 8-10 DAS to facilitate germination. Subsequent irrigation in fennel should be given at an interval of 15-25 days depending upon water holding capacity of the soil, stage of crop and weather conditions. If fennel is grown by transplanting method, irrigation should be given immediately after transplanting

for establishment of seedling and further irrigation must be given similar to direct sown fennel. At critical stage, like flowering and seed formation, fennel crop should not face moisture crisis.

Weed management

The major weeds found in fennel crop are *Chenopodium murale (khartua), Chenopodium album (bathua), Heliotropium ellipticum (Kamera), Melilotus indica (pili senji), Brassica kaber (jangali sarson), Argemone mexicana (satyanasi), Asphodelus tenuifolius (pyaji)* and a parasitic weed *Cuscuta* sp. (*Amar bel*) in some areas. In order to manage weed effectively, it is necessary that first weeding and hoeing should be done at the time of thinning (30 days after sowing) when plants are about 5.0 cm tall. Thinning should be done during first weeding keeping plant to plant distance of 20 cm within the rows. In order to control second flush of weeds, it is necessary to do one more weeding and hoeing at 50 days after sowing. In order to avoid chance weeds at the time germination, it is advisable for pre sowing irrigation which, improve germination and helps the crop to compete with weeds in a better way. After each irrigation, initial weeding is needed till crop covers the ground.

Pests and Diseases

Insects and Pests

Aphids: *Hyadaphis coriandri* is the main aphid species of fennel crop in India. It is the major pests of fennel crop and causing serious damage to the crop resulting in poor quality of seed and reduced yield. Heavy infestation of aphid may cause up to 50 per cent of yield losses in comparison to normal crop. Development of aphid starts at vegetative stage of the crop and continues to develop until seed mature. Maximum colonization of aphids develops on umbel. Nymph and adults suck sap from the tender leaves, which make it weak and shrivelled. Aphid attacks at flowering stage results serious damage.

Thrips: Fennel crop are attacked by thrips during vegetative stages. Crop colonised by thrips at early vegetative stages causes more damage than its attack at full vegetative stages. Thrips species mostly found on fennel plants are *Thrips tabaci, Frankliniella schultzei* and *Scirtothrips sp.* Both adults and nymphs congregate at the leaf sheath or in the flowers and feed on the plant sap by lacerating the leaf tissues causing of drying of leaves and umbels.

Management of Aphids/Thrips:

- Installation of yellow or blue sticky traps at suitable place and height should be done at early vegetative stage of plant for aphid management.

- Use botanicals Neem seed kernel extract (NSKE) 5.0%, Neem oil 2.0%, Azadirachtin 10000 ppm @ 2.0ml/lire and bio-pesticides like *Verticillium lacanii* 1x10^8 CFU's/gm @ 5.0 g. / litre of water as foliar spray on the crops.
- For mite control use bio pesticide *Hirsutells thompsoni* 1x10^8 CFU's/gm5.0 g. /litre of water as foliar spray on the crops.
- In case of severe infestation, need based use of chemical insecticides i.e. Emamectin benzoate @ 10 g a.i./ha or Thiacloprid @ 0.24% or Dimethoate 30EC @ 0.03% to prevent losses.

Defoliator:

Fennel crops are attacked by defoliators from flowering to seed maturation stages. The common species found on seed spice crops are *Spodoptera litura S. exiqua* and *Helicoverpa armigera*. They causes 16 to 20 percent loss when the larval population reached at 2 to 3 larvae/ plant in fennel crop.

Management of Defoliators:

- For managing noctuids moth larvae at field conditions, 4-6 inaculative releases egg parasitoids 150,000 like *Trichogramma Chilonus. T. Brasielensis* @ 150000 parasitoides/ha or starting at first appearance of the moths at 1-15 days interval is found useful.
- Application of NSKE (Neem Seed Kernal Extract) at 5 per cent or Neem oil 2 per cent or commercial formulation of neem-based pesticide gives effective control of early stages of infestation.

Diseases

Ramularia blight (*Ramularia foenicuii*): The disease causes considerable loss in yield due to destruction of foliage and poor development of fruits. Brown to black lesions is formed on the leaves, stem, and peduncle and on seeds. This later shows whitish growth. The infection spread to stem, peduncle and fruits and cover whole plant with a fungal growth of ash colour. Severe infection results in shrivelling and drying up of leaves giving a blight appearance. Flower buds of the diseased plants turn yellowish brown and ultimately dry up.

Management

- Avoid excessive irrigation
- Use disease free seed
- Adopt field sanitation measures
- Use tolerant varieties like AF-1

- Spray the crop with 0.2% Mancozeb or Difolatan or Zineb on 60 to 90 days old crop or at the time of diseases appearance and also during cloudy weather. The spraying should be repeated at 15 days' interval.

Alternaria blight (*Alternaria teniusi*): The disease attacks mainly the inflorescence. Initially, the infection starts from lower buds, turning it yellowish or brown, and due to this whole inflorescence dry up resulting in heavy loss of the yield. Occasionally, the disease is also observed on the tips of the leaves of young plants in the form of brown spots, which may be use to check the growth of the plants.

Management

- Avoid excessive irrigation
- Use disease free seed
- Adopt field sanitation measures
- Use resistant/tolerant varieties like AF-1
- Spray with 0.2 - 0.3 % Mancozeb or Copper oxychloride or 0.1 % Carbendazim and repeat spray at 15 days' interval.

Drooping off (*Sclerotina sclerotinorum* (Lib) de Bary): This disease was first reported from Tonk, Rajasthan in 1965-66. Drooping off was the first characteristics symptoms of this disease. White colony appeared on the infected portion. Stem becomes yellowish brown, whole vascular zone is plugged with black coloured hard sclerotial bodies of 0.5-1.5 cm in length.

Management

- Drench the soil with Vinclozin, Procymidox, Iprodione and Benomyl @ 2 g /ha.

Nemotade (*Meloidogyne javanica*): Though fennel being poor host to root knot nematode, general precautionary measure, as stated below, can take the care of crops.

Management

- Use disease free seed
- Adopt field sanitation measure
- Apply neem cake @ 1000 kg /ha

Harvesting and Yield

Time of harvesting depends upon the type of the products we are interested. In fennel, synchronise maturity of all the umbels is not possible. Hence, picking of umbels is done keeping in view maturity of grain but care must be taken that fully mature grain must remain still green for getting good quality fennel. Near about 170 to 175 days are taken by fennel for its maturity. In fennel, for getting quality produce, it is necessary that harvesting is done before the fruits are fully ripe and harvesting must be completed in three pickings Umbels harvested should dried in 1-2 days and then in shade for 8-10 days. Longer exposure to sun changes the colour and luster of seeds and reduces its quality. In order to get good marketable fennel, it is necessary that over-ripening of umbels should be avoided. Fennel umbels should be harvested 30-40 days after pollination for production of chewing type of fennel. At this stage, size of the seeds is just half of the fully developed seeds and then dried in shade. It reduces the yield but gives high net return as compared to crop harvested at full maturity. The crude fibre content at this stage is 11 % as compared to 15% in the normal fennel. With normal cultivation practices, average yield of fennel is about 12-13 quintal/hectare. However, when improved varieties and package of practices are properly adopted, yield as high as 20-25 quintal/hectare can be obtained.

Processing and post-harvesting management

Well packed fennel seeds are stored in ventilated dry and cool place under ordinary conditions till sowing of next season crop.

Processing:

The fennel seeds are dried in partial shade in the sun and the moisture content of seed should be kept to nine per cent. High seed moisture content may lead to chance of contamination by fungus. The dried, cleaned and graded produce is packed in the standard sized packs/ container and appropriately labelled. The dried seed is filled in the gunny bags lined with degradable environment friendly plastic films. Waste generating packaging material should be avoided. The mature dried seeds are distilled to obtain the essential oil. Hydro or steam distillation method is generally used for extraction of essential oil. On an average, the dried seeds yield 0.7- 2.0% volatile oil. The percentage of volatile oil varies depending upon variety and type of fennel. The volatile oil is lowest in Indian fennel (0.7-1.2%) and highest in European fennel. The oleoresin prepared from fennel have good demand in the international market. The volatile oil should be kept in well-sealed bottles or aluminium containers. The essential oil of fennel is used for scenting soap and as a flavouring material for cakes. The by-product "*arks*" of Saunf, after extraction of essential oil, possess good medicinal

properties for curing indigestion problems at home level remedies. The characteristic odour of fennel oil is due to the high content of anethole.

Fenugreek *(Trigonella foenum-graecum* L.)

Fenugreek of Fabaceae family is an annual crop of diploid species having the chromosome number of 2n=16. Fenugreek has been regarded as the oldest known medicinal plant. Fenugreek originated in South-Europe, Mediterranean area and Western Asia. India is also native place of fenugreek and found growing wild in Kashmir, Punjab and upper Gangetic planes. The most common Indian name is *Methi* and there are many other popular regional names. In Tamil it is known as *Vendayam* and in Telugu as *Menthulu.* The genus *Trigonella* have 50 species, most of which are of an oriental origin in the Iranian-Indian region. Out of these, total eleven species of *Trigonella* genus occur in India, out of which *Trigonella foenum-graecum* L. (common fenugreek) and *Trigonella corniculata* L. (*Kasuri* type fenugreek) are cultivated in India. Fenugreek is mainly cultivated in India, Argentina, Egypt, France, Spain, Turkey, Morocco and China. India is the largest producer of fenugreek in the world. In India, Rajasthan, Gujarat, Uttaranchal, Uttar Pradesh, Madhya Pradesh, Maharashtra, Haryana and Punjab are the major fenugreek producing states. Rajasthan is producing 80 percent of fenugreek in India hence it is considered as fenugreek bowl of the country. Fenugreek is commercially important spice crop due to its multifarious uses and is extensively grown in almost every part of the country during winter season for seeds, tender shoots, and fresh leaves.

Fig. 4.8: Fenugreek leaves

Fig. 4.9: Fenugreek seeds

Important Varieties

Number of good varieties suitable for different agro climate region have been developed. Salient feature of some of the important cultivated varieties are as given below:

State-wise recommended varieties

Name of State	Important Varieties
Andhra Pradesh	Lam Selection-1
Bihar	Rajendra Kranti
Haryana	Hisar Sonali, Hisar Suvarna, Hisar Mukta and Hisar Madhavi (HM-350)
Gujarat	GM-1
Rajasthan	Ajmer Methi 1 (AFg-1), Ajmer Methi 2 (AFg-2), Ajmer Methi 3 (AFg-3), Ajmer Methi 4 (AFg-4), Ajmer Methi 4 (AFg-4), RMt 1, RMt-143 and RMt 305
Uttar Pradesh and Uttaranchal	Pant Ragini, Pusa Early Bunching and Pusa Kasuri
Tamil Nadu	Co-1

Land preparation and tillage

Soil with good drainage facilities is suited for cultivation of fenugreek but it grows best on well–drained loamy soils. Soils rich in organic matter content and having sufficient clay-loam is highly preferred by fenugreek as compared to the soils containing higher sand or gravely material. Under rainfed condition, black cotton soils are best for successful cultivation of fenugreek. Fenugreek can tolerate salinity level up to 8.4 pH but prefers neutral soils as they are the best suited soil having a pH range from 6.5 to 7.5. Preparation of land should be done by cultivating 3-4 times for bringing the soil to a fine tilth required for fenugreek sowing. It is also necessary for planking the soil immediately after ploughing to avoid loss of soil moisture and to break the clods. In order to take dryland crop under black cotton soil, it is necessary that the field must be kept either fallow or short duration crop like green gram or black gram should be grown and harvested as early as possible at physiological maturity stage. In light soil, less number of ploughing are required. At the time of sowing, soil must be friable to obtain better seed bed for better seedling emergence and their further establishment and growth.

Cropping system

Fenugreek can be successfully grown as mixed or intercrop. It is a leguminous crops. Hence, it very much suitable to fit as a component crop in most of inter

cropping systems involving fennel, coriander, ajwain, dill and winter vegetable crops. Likewise, crops should be grown as per standard principal of crop rotation. Some of the crop rotation systems suggested are:

- Maize / pearl millet- Fenugreek
- Sesame – Fenugreek
- Sesame –Fenugreek – Summer Maize

Sowing time

Being a cool-season crop, sowing Fenugreek in months of October and November are most congenial in northern plains whereas, depending on altitude, March to May is the best sowing time in hilly tracts. Fenugreek for fresh leaves may be grown round the year in areas with mild climate except extreme hot months of summer and rainy season. In southern states viz., Karnataka, Andhra Pradesh and Tamil Nadu, fenugreek can be sown twice, once in *Rabi* (September–December) and again in *Kharif* season (June–July). *Kasuri* type of varieties prefers extra cool weather for longer duration. Thus, these type of variety can be raised more successfully in northern states during winter than the southern states of India. Time of sowing should be so adjusted that the pod development and seed maturity phase may coincide with a dry and rain free period for getting higher yield.

Seed rate

The purpose, for which the crop is sown, is a most important parameter for determining the quantity of seed required. To raise a healthy crop and to obtain better yield with quality produce, proper seed rate should be maintained. If it is less than the requirement, for per yield, the plant spacing will be more and crop density will be less. Higher seed rate leads to high plant population resulting in poor plant growth and poor quality produce due increase competition for water, nutrition, light etc. 20 – 25 kg/ha seed for common fenugreek and10–12 kg/ha seed for *Kasuri Methi* is required.

Seed treatment

Being a leguminous crop, Fenugreek fix 283 kg nitrogen per hectare per year from the atmosphere into the soil. In order to get better growth and yield, seed should be treated with *Rhizobium meliloti* local culture prior to sowing, especially when the crop is sown in new field. Therefore, it is also recommended to treat the seeds with *Rhizoctonia meliloti* culture before sowing. In order to control early fungal disease, it is necessary that seed should be treated with bavistin or thiram @ 2.0g/kg seed.

Sowing method

Fenugreek can be sown either through broadcasting or through line method. In broadcasting method, seeds are broadcasted in well- prepared flat seedbeds and then racking of the bed surface is done prudently. Sowing of fenugreek in lines is better than the broadcasting because it facilitates the intercultural operations like hoeing and weeding. Sowing of fenugreek is done at line spacing of 25-30 cm and later the plants are thinned to maintain 10-15 cm spacing within the lines. It germinates in 5-7 days after sowing. Depth of sowing should be kept 3-4 cm and seed of *Kasuri Methi* should be sown at 1.0-1.5 cm depth.

Manures and Fertilizers

The fenugreek crop has been reported to show very good responsive behaviour towards absorption of both macro as well as micro nutrients. Generally, it is recommended to apply FYM @ 10 tonnes/hectare which helps in enhancement of vegetative growth of plant. The microbial inoculation with *Azospirillum*, *Azotobactor* sp. and *Rhizobium* has been reported to be suitable means for organic cultivation of fenugreek. The *Azospirillum* in combination with organic manure @ 10 tonnes/hectare resulted in high organic seed yield. Doses of fertilizer depend on fertility status of the soil, type of soil and variety to be grown. Application of 40 kg N/ha significantly increased the mean plant height, branches and pods/plant, pod length, test weight and straw yield compared with 0 and 20 kg N/ha. Seeds/pod and seed yield increased significantly with the application of 40 kg N/ha. Compared with the control, P at 40 kg/ha produced significantly higher mean number of branches, pods/plant, test weight, straw and seed yields than 20 kg P/ha. Rhizobium inoculation resulted in significant increases in number of branches per plant, pod length and test weight and improved yield compared with the uninoculated control.

Irrigation

Fenugreek, mainly grown as irrigated crop, need application of light irrigations at frequent intervals for quick growth. It can also be cultivated under rain fed condition in medium to heavy type of soil. If there is plenty of moisture in soil then sowing of fenugreek is done and irrigation is applied when the seedling attains 2 – 4 true leaves. A light irrigation should be applied before sowing, if initial moisture in the soil is inadequate at the time of sowing, and another light irrigation should be given on third day to facilitate rapid and uniform germination. Afterward, subsequent irrigations should be given at 12 to 15 days interval depending on soil type, season, rainfall, and other temporary weather conditions. For getting quick foliar growth, it is necessary to apply frequent and light irrigations if cultivation of crop is done for green leaves and each cutting

should be followed by a light irrigation. The early growth period and seed setting are the critical stages for irrigation in the crop which is grown exclusively for grain or seed purpose. Optimum irrigation is necessary because if too much irrigation is applied, it harms the crop by increasing the incidence of root rot at any stage and especially at flowering powdery mildew. In fenugreek, application of seven irrigations at 1.0 IW/CPE ratio is optimum in Gujarat conditions. But it is necessary to take care for avoiding water stress at pod and seed development stages. Normally 6-7 irrigations are required in light soil and 4-5 irrigations are needed in heavy soils.

Weed management

During initial period, fenugreek experiences more weed problem due to its slow Initial growth but in later stages, when crop canopy fully developed, weeding is not at all required as the crop itself suppresses the weeds. There is little reduction in plant growth and yield due to weed flush which emerges at 30-40 DAS. Therefore, first 30-40 days have been identified as a critical period with respect to crop weed competition in fenugreek. 2–3 hand weeding are required in fenugreek for keeping the crop weed free and reducing the crop weed-crop competition. First hoeing and weeding should be done when the fenugreek plants are of 5 cm tall. Two hoeing and weeding should be done for fenugreek crop – first weeding and hoeing at 15-20 days after sowing, along with thinning of the plants, and second weeding and hoeing at 40-50 days after sowing, which should be done for healthy crop and higher yield. In order to ensure effective weed control, it is necessary to adopt integrated weed management using pre-sowing application of Pendimethalin @ 1 kg/ ha, or pre sowing application of Fluichlorin @ 0.75 kg/hg in 500 – 600 litres of water, with one hand weeding at 50 DAS. It has been found that application of different herbicide *viz*. Pendimethalin @ 0.75 kg/ha and Fluchloralin at 1.0 kg/ha are superior for effective weed control in fenugreek. Application of Oxadiargyl @75 g a.i./ha just after sowing with one hand weeding at 45 DAS is best integrated weed management practice in fenugreek crop.

Pests and Diseases

Insect-Pests

Aphids (*Acrythosiphonpisum*, Henis. and *Aphis craccivora*, Koch.): Both nymphs and adults suck sap from the tender leaves thus reducing market value. The severe infestation affects the yield and quality of leaves badly.

White fly (*Bemisia tabaci*): White fly is serious pest of fenugreek in some area. It attacks the crop at early stage to pod formation stage. Nymph and adult suck the sap of plant causes yellowing of plant and subsequently plant die.

Jassids (*Empoasea* spp.): Jassids attack on fenugreek crop at early stage. Nymph and adult suck the leaf sap causing browning of leaves.

Mites (*Pertobialatens*): Infestation of mites can be seen occasionally. The insect mostly feeds on young leaves. The severe infestation affects the yield and quality of leaves. Small mites are seen on lower side of leaves and when serious, cause webbing and feed within the web. Plants get stunted at severe infestation.

Management of Aphid/White fly/ Jassids/ Mites:

- Trapping and monitoring with yellow stick trap.
- Timely sowing of crop helps in lower build-up of pests' population. Late sown crops are more prone to heavy attack by number of insect pests.
- Recommended doses of nitrogenous fertilizers should be applied. Because higher application of nitrogenous fertilizers causes more succulent to the crop.
- Spraying of Neem Seed Kernel Extract (NSKE) @ 5 % or Neem oil 2% effectively checks the early population build-up of aphids on the crop.
- Application of entomopathogen *Verticillium lecanii* (10^8 spores/g) powder formulation @5.0 g/litre of water give good result.

Leaf minor (*Empoasea* spp.): Excess mining of leaves at early stage causes stunting growth of plant. Heavy infested crop gives less production.

Control

- Spray dimethoate 0.03% or Emamectin benzoate @ 10 g a.i./ha
- Spray neem oil (2%)

Diseases

Root rot (*Rhizoctoniasolani* Kuhn.): This is a soil borne disease. The symptoms include varying degrees of rotting of the root leading of foliage yellowing generally in 30-45 days old plants. Later on, the affected plants dry up and wither. It is a serious problem in major fenugreek growing areas and drastically reduces the yield.

Management

- Seed treatment with thiram or captan @ 2 to 3 g/kg of seed.

- Seed pelleting with antagonistic fungi like *Trichoderma. viride*, *T. harzianum* (Talc based formulation @ 4 g/kg of seed) followed by soil application of neem cake 150 kg/ha.
- Drenching of carbendazim (0.1%) once at initial appearance of disease and after one month.
- Deep summer ploughing of field and adoption of crop rotation practice.
- Use of bio-inoculants *Azospirillum* or *Azotobactor* plays significant role in reducing incidence of root rot to 8.2%.

Powdery mildew (*Erysiphe polygoni* D.C. and *Laveillula tourica* Lev.): The disease generally appears late in the season. The symptoms include the appearance of whitish fungal growth on leaves and other above ground parts of the plant. The disease becomes serious at temperatures between 15°- 25°C and at a relative humidity more than 60%.

Management

- Dusting with 300 mesh sulphur (25 kg/ha) or by spraying wettable sulphur (0.25%) or hexaconazole (0.1%) twice commencing from initiation of disease at 15 days' interval.
- Grow resistant /tolerant varieties.

Downy mildew (*Peronospora trigonella* Gaum.): Symptoms include the presence of yellow patches on the upper surface and downy growth on the lower surface in the corresponding areas. In the advance stage of infection, the leaves turn yellow and shed, thus plant growth is checked adversely.

Management

- Spray 400-500 litre solution of 0.2% copper oxychloride or chlorothalonil. Repeat the spray after 10 days' interval, if needed.
- Spray of metalaxyl + mancozeb (1g/litre) at 15 days' interval is also recommended.
- Give hot water treatment to seed before sowing.

Damping-off (*Pythium aphanidermatum*): The infected seedlings appear water-soaked, discoloured and soft, emitting a bad odour. The infection mostly occurs at or below the ground level and the seedlings topples down and withers off.

Management

- To minimize the source of infection seed treatment with carbendazmim (2.5 g/kg seed) is recommended in reducing the seedling mortality.

- Use of soil amendments like neem cake @ 10 quintal/hectare and farmyard manure @ 10-25 tonnes/hectare is beneficial.
- Adoption of proper crop rotation and deep summer ploughing.
- The antagonistic fungus, *Trichoderma viride*, and soil application of neem cake effectively control the disease.

Rust (*Uromycesanthyllidis*): The yellow spots bearing aecia in clusters are earlier symptoms of the disease. The disease is observed in the form of minute brown pustules on both the surfaces of leaves. The disease is of minor importance but, under cool and wet climate in northern India, entire plant may be damaged with the disease.

Management

- Adopt good cultural operation and field sanitation

Harvesting and Yield

If fenugreek is cultivated for leaf purpose, then common *Methi* becomes ready for harvesting at 20 days of sowing and *Kasuri Methi* becomes ready for harvesting 25-30 days after sowing and subsequent cuttings may be taken at an interval of 15 – 20 days. The crop when grown for dual purposes after taking one cutting, which does not affect the seed yield, is left for seed production. The harvested crop is bunched and marketed. The cutting is usually done with sharp knife by leaving stubs 3- 4 cm above the ground level and after taking 4–5 cutting the crop, grown exclusively for green leaves, is uprooted. If fenugreek is harvested late, then there is chance of development of bitter taste. Practically, fenugreek crop, which is grown for grain, takes 120-165 days in harvesting depending upon variety and season of growing the. The entire plants are either pulled out from the base with the use of sickle, when 70 % of the pods turn yellow, and made into small bundles for drying them in sun. The seeds are separated with winnowing. The grain of fenugreek is dried up to 7-8% moisture and afterward grains are cleaned, graded and packed in deferent type of packages as per the requirement viz., plastic bags cloth bags, gummy bags lined with polythene, CAP/MAP, vacuum packages etc. Usually, the cultivars yielding higher grain yield tend to produce low fresh green leaf yield. Common type fenugreek varieties normally give a fresh green leaf and seed yield of 70-80 and 15-20 quintals/hectare respectively and *Kasuri* type 80 – 100 quintals green leaves per hectare.

Processing and post-harvesting management

Keeping in view the requirement of targeted market, the post-harvest operations are advised to follow suitably for green leaves as vegetable, dehydrated leaves and seeds. In case of fresh greens, the edible portion is the tender leaves and stem, which are cut to length of about 7-10 cm. After harvesting, the yellow, diseased and damaged leaves are trimmed off and thereby healthy and disease free leaves are tied into small bunches for the convenience in handling and marketing. The dried leaves can be stored for one year for further use in off-season. The palatability of fenugreek leaves improves with steaming and with addition of seasoning rather than with boiling or frying. Every part of this multipurpose crop is useful and utilized in one or the other form as food, fodder, medicine, and cosmetics. Its green fresh leaves and tender immature pods are used as green cooked vegetable. The seeds are also used for making dye. In certain parts, the green or dry fodder is usually fed to the cattle. It is recognized well as commercial uses in syrups, pickles, baked foods, condiments, chewing gums, icings, and cooked food seasonings.

Nigella (*Nigella sativa)*

Nigella an important annual herbaceous plant belonging to family Ranunculacea is an important seed spice crop. Nigella crop is native of Mediterranean region encompassing West Asia to Northern India and it has long been domesticated. It can be frequently found growing wild as a weed in cultivated crops. In ancient Greek, Roman and Hebrew texts, it has been mentioned as black cumin as a condiment and component of herbal medicines and was reportedly introduced to Britain in 1548. Nigella is a minor seed spice crop mainly cultivated in Morocco and Northern India. It is cultivated in in sub–Saharan Africa, particularly Niger and eastern Africa, especially Ethiopia, where it is also used in fish preparation. Seeds of nigella are mainly used for medicinal purpose in South-East Asia. In ancient Egypt, nigella seeds were found in the tomb of Tutankhamun. The name “Nigella” has been derived from the Latin “Niger” which means black. Nigella is mainly called as black cumin and in different countries it is popular by different names. In English, it is also called as black cumin or small fennel. Since time immemorial nigella has been used as a condiment and it mainly found as wild in India. In many texts, nigella is quoted as black cumin and due to similarity in common names, one may be confused with other spices of family Apiaceae, viz. Kala Zira (literally black cumin – *Bunicum persicum Bioss. Fedtsch* syn. *Carum bulbocastum* Koch.) and Siah Zira (literally black cumin – *Carum carvi* L.), The seeds of Nigella have been used as spices from ancient times in India when preparing pickles as one of the ingredients which has the properties of a preservative. India is known to be the largest producer of Nigella in the world.

The other producing countries are Sri Lanka, Bangladesh, Nepal, Egypt, Iraq and Pakistan. In India, it is commercially cultivated in Punjab, Himachal Pradesh, Madhya Pradesh, Bihar, Jharkhand, Assam, West Bengal and Andhra Pradesh.

Fig. 4.10: Nigella

Improved Varieties

In India, different varieties have been developed for nigella cultivation in different part of the country.

State-wise recommended varieties

Name of State	**Important Varieties**
Bihar	Rajendra Shyama
Rajasthan	Ajmer Nigella-1 (AN-1), Ajmer Nigella-20 (AN-20),
Uttar Pradesh	Azad Kalonji
Uttarakhand	Pant Krishna
Madhya Pradesh	NS-44 and NS-32

Climate

Nigella is a cool season crop and is cultivated in the northern plain during winter season. It requires fairly warm weather during sowing with temperature of 20-25°C for successful growth. Nigella crop is very sensitive to frost at any growth

stage. Normally, it is sown in late spring–early summer but in regions with wet and dry seasons, it is sown just after the first rains. For early growth, cold weather is congenial and it requires warm sunny weather during seed formation and maturity. For maximum plant growth and yield of nigella, cooler climate with a temperature range of 5-25ºC is required. Although, nigella is grown under diverse range of environments but flourishes well in cooler regions with the optimum being 12-14ºC. Rainfall of 400-500 mm helps in good growth of the plant. Excess water must be drained out to the field as plant is susceptible to water logging and frost sensitive at any growth stage. Plants begin flowering 80-100 days after sowing depending on the average temperature. Higher temperature accelerates flowering, but if prolonged, it generally reduces the number of flowers or flower drops after pollination. It takes 130-135 day for maturity.

Soil and Land Preparation

For successful cultivation of nigella, wide range of soils, which are rich in organic matter and free from water logging, can be used. The successful cultivation of nigella requires loamy medium to heavy soils. The land should get sufficient sunlight free from shade. The place should be airy with good provision of irrigation water. Soil pH range near about neutral reaction but it can be grown well on soil of pH of 5-8. The most favourable soil for nigella is loamy, medium to heavy soils with better fertility levels. Preparation of field should be very good for getting good germination, growth and yield of nigella. 2-3 ploughing are required for successful cultivation of nigella and first ploughing should be done by soil turning plough followed by light ploughing by harrow or cultivator. Soil should be prepared well in order to get better tilth. The surface of field should be smooth and well levelled which may be divided into convenient size of beds. Pre-sowing irrigation should be given for better and uniform germination of seeds.

Seed Sowing and Sowing method

Time of sowing is an important agronomic input without incurring any cost but influence yield. Therefore, it is necessary that the seed of nigella should be sown at proper time for getting higher yield. Optimum time for sowing is Mid-Sep to Mid-Oct. The seed can be sown up to November but late sown crop give poor yield of nigella. Nigella is propagated by seed. Seeds are sown at row spacing of 30 cm and plant spacing of 15–20 cm and a seed rate of 6-8 kg/ha is required. Under Indian conditions, sowing during the month of October has been found appropriate. Nigella takes 12 days for germination. Nigella is sown by two methods *viz.* line sowing and broadcasting. However, line sowing is better because it facilitates intercultural operation and plant protection measures. The

seeds are sown 1.5-2.0 cm deep at row spacing of 30 cm and plant to plant spacing of 15 cm. Immediately after sowing, light irrigation can be given, if initial moisture is less, for ensuring germination of seeds within 10 days after sowing. Care should be taken that during irrigation, the water should not flow at faster speed otherwise seed may be carried out and gather towards bund resulting in uneven distribution of plants.

Manure and Fertilizers

The application of manure and fertilizer should be done based on soil test report of soil. Prior to field preparation, it is advisable to apply 5-10 tons of well decomposed FYM which should be incorporate well in the soil. In addition, apply 40 kg N, 20 kg P_2O_5 and 20 kg K_2O through fertilizers. Total quantity of phosphorus, potash and 1/3 dose of nitrogen should be applied as basal dose while rest of the nitrogen should be applied in two equal splits, first at 30 days after sowing while rest at flowering as top dressing in standing crop. If initial crop growth is poor, then 1.0 per cent solution of urea can be sprayed after 3 weeks of sowing.

Irrigation management

A light irrigation can be given just after sowing for proper germination, if soil moisture is not sufficient at the time of sowing, and further irrigation should be given at 15-25 days interval depending on climate and type of soil conditions. In the light soil, frequent irrigation should be applied and in heavy soil, duration of irrigation interval should be kept higher. In all 3-5 irrigation are sufficient to raise successful crop. In order to stop flowing of soil and seed, precaution should be taken during irrigation that water flow should be slow. In nigella, the critical stages of irrigation are flowering and seed formation. Therefore, crop should not be allowed to face water stress at flowering and seed formation stages. Excess moisture causes root rot so irrigation should be given as per requirement of crop.

Weed management

Initial growth of nigella is very slow hence very much susceptible to incidence of weed. Weed consist of broad and narrow leaf are common in field. Major broad leaf weed flora associated with crops are *Chenopodium album* (Bathua), *Chenopodium murale* (Kharbathua), *Amaranthus viridis* (Janglee Cholai), *Melilotus indica* (Safed Senji), *Anagalis arvensis* (Krishna neel), *Portulaca olaracea* (Junglee Palak), *Vicia ativa* (Gengla), *Argemone Mexicana* (Satanashi), and *Spergula arvensis* (Satgathya). The major narrow leaf weed found in Nigella are *Plantago pumila* (Zeeri), *Avena fatuva* (Junglee Zai), *Cynodon dactylon* (Dhoob grass), *Dactylocteum aegypticum* (Makada), *Eochinochloa colomum* (Samagrass)

and *Asphodelus tenufolius* (Pyaji). Some weeds of Cyprus family are *Cyprus rotundus* and Cyprus *eriyia* (Motha). Field should be kept clean and weed free during 30-60 days of sowing by hand weeding. For effective control of weeds, nigella need 2-3 hoeing and weeding. Therefore, it is necessary to do first weeding at 30 days after sowing the second on 60 days after sowing. If required, third weeding can also be done. During first weeding, the plant should also be thinned to the desired distance. Chemical control of weed can be done with a pre plant application of the herbicide. In order to control weed during vegetative phase, pre-plant incorporation of fluchloralin 0.75 to 1.0 kg/ha or pre-emergence application of Oxadiargyl @ 0.075 kg /ha or pre-emergence application of Oxy flurofen @ 0.15 kg /ha or Pendimethalin @ 0.75 to 1.0 kg/ha after dissolving in 400-500 litre of water is recommended. Excess use of herbicide imparts soil toxicity and is harmful to soil micro fauna, flora and soil builder elements. Therefore, it is necessary to adopt eco-friendly approach like mulching, manual weeding/ hoeing and crop rotation to reduce weed population and improve quantity and quality of crop yield.

Pests and Diseases

Insects-Pests

Capsule borer: Borer infestation starts at fruit forming stages. The borers attack young fruits and capsules, and bore inside the fruit. Damaged capsule fails to form seed in it. Early detection and appropriate control measures should be necessary to prevent damage of borers on crop.

Control

It can be controlled by application of Chloropyriphos 0.04%. Spraying should be done twice or thrice at interval of 10-12 days. If the infestation is detected at early stage, hand picking and distraction of larva should be advised to check the population of the borer.

White fly: The population of white fly is generally found at early stages of crop growth. Adult and immature stages found on lower surface of leaves and feed on them. They suck the sap of leaves. Affected leaves turn white to pale grey in colour. Severely affected plant fails to produce seed capsule.

Control

- It is sap sucking insect that can be suppressed by spraying of systematic insecticides. Spraying of Imidachlorprid 0.005% or Dimethoate 0.03% effectively control white fly population on the crops.

- Application of botanical insecticides like NTSKE @ 2-5%. Neem oil @ 1-2% also found effective in reduction of white fly population.

Termites: This insect damage Nigella crop, generally at full vegetative growth stage, by cutting the plant stem near soil surface and the plant falls down. Initially, plant look like lodging but ultimately die. To monitor this insect, regular field inspection should be made to detect the appearance of the pest.

Control

- Application of Phorate10 G @ 10 kg/ha or Fenvalrate Dust 1% @ 25 kg/ha in the soil near the base of the plant can be useful to brine this pest tinder control. Broadcast chloropyriphos 20 E.C. or Endosulfan 35EC @ 4 lit./ha mixed with sand is also effective control of termites.

Diseases

Root rot: Root rot is major disease of Nigella plant. Affected plant show wilted symptom and die within 10- 20 days of infection.

Management:

The seeds treatment (10g/kg seed) and soil application (2.5 kg/ha mixed in 50 kg FYM or vermicompost) with consortia of Trichoderma viride and Pseudomonas fluorescence prove effective in control of disease.

Harvesting and Yield

Nigella takes 135-150 days for maturity. Harvesting of nigella should be done after the seeds attained full maturity in capsule and their colour turned to full brown / black colour. The harvesting of nigella should be done at appropriate time because delay in harvesting may cause shattering of seeds. With the adoption of scientific cultivation practices, we can obtain average seed yield of 5-10 quintal per hectare. The seeds should be separated by rubbing plants or by stick beating. The seeds are, thereafter, winnowed and dried.

Processing and post-harvesting management

The seeds contain 0.5 to 1.6% of essential oil that is used in food, flavour and pharmaceutical industries. To obtain the oil, seeds are crushed and distilled with steam. A yellowish-brown volatile oil with a specific odour is received. Nigellone, a carboxyl compound, is the important constituent possessing medicinal and preservatives quality. The fatty oil obtained by the extraction of the seed is reported to be used for edible purposes. Extraction with benzene and subsequent steam distillation of extract to remove the volatile oil gave about 31% of reddish brown, semi-drying oil. The dried black seeds of Nigella are the commercial

product being used in food, flavour and medicines. The seeds of Nigella are being used as spice from the ancient times in preparation of pickles, as one of the ingredients. The oil can be used as a stabilizing agent for edible fats.

Ajwain (*Trachyspermum ammi* L.)

Ajwain, also known as carom seed (*Trachyspermum ammi* L.) in India, is native of Egypt belonging to Apiaceae family. Ajwain is a popular minor seed spice crop in India. The most common Indian name is ajwain and there are many other popular regional names. It is locally known as omum and vamu in Tamil and Telgu respectively. It is mainly cultivated in India, Egypt, Afghanistan, Pakistan, Persia, Iran, and North Africa. In India it is mainly cultivated in the states like Rajasthan, Gujarat, Andhra Pradesh, Madhya Pradesh, Bihar, Uttar Pradesh, Tamil Nadu and West Bengal.

Fig. 4.12: Ajwain plant

Fig. 4.11: Ajwain flowers

Fig. 4.13: Ajwain seeds

State-wise Recommended Varieties

Name of State	Important Varieties
Andhra Pradesh	Lam Selection-1, Lam Selection-2
Bihar	R.A. 1-80, R.A. 19-80
Gujarat	Gujarat Ajwain-1
Rajasthan	Ajmer Ajwain 1 (AA-1), Ajmer Ajwain 2 (AA-2), Ajmer Ajwain 73, Ajmer Ajwain 93 and Pratap Ajwain-1

Soil and Land preparation

Ajwain can be cultivated in wide range of soils but well drained loamy soils are best for successful cultivation. If adequate drainage facilities are available then organic matter rich clay-loam soil may be used for cultivation of ajwain. The light

sandy or gravely soils are not suitable for cultivation of ajwain. The heavy soils, due to higher moisture retention capacity, are very congenial for cultivation of ajwain under rainfed situation. The soils having a pH range of 6.5 to 7.5 are best suited for higher yield, however, slight saline soil also can be used for cultivation of ajwain. In order to ensure better germination of seed and proper growth, it is necessary to develop fine tilth of soil. The soil turning plough should be used for first ploughing and afterward 2-3 light ploughing should be done by harrow or cultivator for getting better and fine soil tilth. Planking should be for better soil moisture conservation. For the control of termite, apply 20-25 kg/ha of quinalphos (1.5%) or methyl parathion (3%) at the time of last ploughing.

Name of State	**Important Varieties**
Andhra Pradesh	Lam Selection-1, Lam Selection-2
Bihar	R.A. 1-80, R.A. 19-80
Gujarat	Gujarat Ajwain-1
Rajasthan	Ajmer Ajwain 1 (AA-1), Ajmer Ajwain 2 (AA-2), Ajmer Ajwain 73, Ajmer Ajwain 93 and Pratap Ajwain-1

Climate

Being a cold loving crop, it is mainly grown during *Rabi* season in India. It can also be grown as *kharif* crop in some pockets of our country. It prefers moderately cool and dry climate for good plant growth and flowering. High humidity at flowering is harmful. Hence, at this stage effort should be made to avoid high humidity. Cloudy weather and occurrence of high moisture invites insect-pests and diseases. During growth period, it needs a temperature between 15-27^{0}C with relative humidity of 60-70 per cent but requires relatively warm weather during seed development. However, ajwain has moderate level of tolerance to drought and it possesses wider climatic adaptability as it can be successfully grown in *kharif* season too.

Cropping system

Ajwain is very well suited as mixed or intercropping with tall growing plants. In order to ensure sustainability and maintain soil fertility, it is wise to adopt efficient crop rotation ideally suitable for the region. The important crop rotations are as under

- Green gram or Black gram in kharif season followed by Ajwain in *Rabi* season
- CLuster-bean or Cowpea in kharif season followed by Ajwain in *Rabi* season
- Green gram in *kharif* season followed by Ajwain in *Rabi* season
- Maize or Pearl-millet in kharif season followed by Ajwain in *Rabi* season

Sowing time

Time of sowing is important non monitory agro-technique affecting yield as well as incidence of pest and diseases. Ajwain is cold loving crop hence mainly grown during *Rabi* season in most of the part of India. Ajwain can also be grown as *kharif* crops in some pockets of our country. September and October is the congenial month for sowing of ajwain in northern plains, whereas, as a *kharif* season crop, it is sown from July to August. In south India, specifically Andhra Pradesh, Karnataka and Tamil Nadu, sowing of ajwain is usually done in the middle of August and harvested around December and January.

Seed rate

Requirement of seed per hectare depends on size of seed and variety, however due to small size of ajwain seed, seed requirement is less. The requirement of seed per hectare also depends on season in which the crop is sown. For sowing of ajwain, normally 2.5 – 3.0 kg seed per hectare is required for sowing as *Rabi* season crop and 4-5 kg seed per hectare is required for sowing as *kharif* season crop. The initial soil moisture in the soil should be proper for ensuring germination.

Seed treatment

The use of bio inoculant *Azospirillum* or *Azotobactor* as seed treatment before sowing has proved beneficial in getting higher yield. The treatment of ajwain seed should be done with bavistin or Captan or thiram @ 2.0- 2.5 gm/kg seed for control seed and soil borne diseases.

Sowing method

Normally, sowing of ajwain is done either by broadcasting or by drilling in rows that are 45 cm apart under irrigated conditions and 30 cm apart under rainfed production system. The germination of ajwain seed takes place in about 10-12 days. In order to get better dry matter accumulation per plant, it is necessary that spacing should be maintained at 20-30 cm. In order to facilitate inter culture operations, sowing of ajwain in lines is appropriate. Sowing should be done at 1.0 to 1.5 cm deep in the soil for ensuring better germination. Dry sand should be mixed with seed before sowing for ensuring uniform spread of seed

Manures and Fertilizers

The manure and fertilizers should be applied based on soil testing report of fertility status of the field's soil. In general, apply 10 tons of FYM or compost for getting better yield of ajwain before ploughing and under irrigated situation, apply 40 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare at the time of last ploughing in the soils. In standing crop, an additional dose of 40 kg nitrogen should also be given in two equal splits, one at 45 days after sowing and second before flowering, for ensuring better growth and development of crop. It has been found that increasing N application is better for higher seed yield.

Irrigation

Ajwain is successfully cultivated both under irrigated and rainfed farming situation. Appropriate moisture level should be maintained in root zone for ensuring better growth, development and yield of ajwain crop. Normally, it is better to apply near about 5 irrigations for getting better yield of crop. For better germination of ajwain, it is necessary to apply irrigation at 4-5 days after sowing which is helpful for breaking down the soil crust. Depending on climate and soil type, subsequent irrigations should be applied at 15-25 days interval. In order to get higher yield, it is better to apply irrigation at 0.8 IW/CPE ratios.

Weed management

Initial growth of ajwain is slow which results weed problem. Hence, it is necessary to keep the field free from weeds. Initial 40-45 days of sowing are very critical for managing weed to get higher yield of crop. After 30 days of sowing, first weeding, accompanied by thinning from rows, is better for weed management in ajwain and subsequent weeding should be done at 30 days intervals. For effective weed management, 2-3 weeding and hoeing is sufficient. Pre-emergence application of Oxadiargyl @ 0.075 kg/ha or Pendimethalin @ 1 kg/ha or Oxadiargyl @ 0.075 kg/ha just after sowing along with one hand weeding at 45 DAS is the most effective and economical method of weed management in ajwain. The sufficient moisture in the soil should be maintained at the time of application of weedicides.

Pests and Diseases

Insect-Pests

Seed Bug (*Nysus* spp.): It found on the crop during seed formation stages and it feeds on developing seed. Heavy infested plants produce less seed yield.

Control

- Trapping and monitoring with yellow stick trap.

- Timely sowing of crop helps to lower build-up of pests' population. Late sown crops are more prone to heavy attack by number of insect pests.
- Recommended doses of nitrogenous fertilizers should be applied. This is because higher application of nitrogenous fertilizers causes more succulent to the crop.
- At high aphid population, any one of the synthetic insecticides should be sprayed *i.e.,* Dimethoate 0.03%, Metasytox - 0.03%, Emamectin benzoate @ 10 g ai/ha, or Imidachlorprid - 0.005%.

Seed Borer (*Systole albipennis*): Larva feeds in side and destroys the embryo and/or endosperm consequently. Chalcid wasp does not cause much of yield reduction but presence of insect body part inside the seed make unfit for export purposes. Approximately 20% of seed damage has been observed in ajwain.

Management:

- Foliar application of insecticides at flowering stages at 10 days' intervals can manage the pests. Insecticides like neem oil (2%), Thiomethoxam (0.025%), and Imidachlorprid (0.005%) are effective against this pest.

Diseases

Root rot (*Rhizoctonia solani* Kuhn.): This is a soil-borne disease. The symptoms include varying degrees of rotting of the root leading to foliage yellowing generally in 30-45 days old plant. The affected plants later on dry up and wither. It is a serious problem in ajwain growing areas and drastically reduces the yield.

Management

- Seed treatment with Thiram or Captan @ 3 g/kg of seed.
- Soil application of neem cake @ 150 kg/ha and seed pelleting with antagonistic fungi like *Trichoderma viride*, *T. harzianum* (Talc based formulation @ 4 g/kg of seed) can be used to manage the disease.
- Drenching of Carbendazim (0.1%) on the appearance of disease and after one month.
- Deep summer ploughing of field and adoption of crop rotation practice.
- Use of bio-inoculants Azospirillum or Azotobactor plays significant role in reducing incidence of root rot to 8.2%.

Powdery Mildew (*Erysiphepolygoni* D. C.): The disease generally appears late in the season and is of minor importance. The symptoms include the appearance of whitish fungal growth on leaves.

Management

- Dusting with Sulphur (25 kg/ha) or by spraying wettable Sulphur twice at flowering stage at 15 days' interval.

Harvesting and Yield

Ajwain crop takes near about 130-180 days for maturity depending upon the variety and season. In this way, harvesting of ajwain is usually starts from March to April. At maturity, flowering of ajwain stop and seed begin to develop and become brown in umbels. The serrated sickle, the most important farm implements, is used for efficiently harvesting the crop manually. The bundles of ajwain should be stacked for drying and be kept upside down for maintaining quality of seed. After sun drying, threshing should be done to separate the fruits by beating with sticks. Threshing of ajwain seed can also be done by thresher which saves time labour etc. Under good management condition, average yields of 12-15 quintal/hectare under irrigated condition and 4-6 quintal/hectare under rain fed conditions could be obtained.

Processing and post-harvesting management

Seeds are stored in gunny bags lined with polythene film. Vacuum gravity separator is used for cleaning ajwain seeds. The properly cleaned ajwain seeds are stored with an initial moisture level of 7-8% and at an equilibrium relative humidity of 40%. Ajwain seeds well packed are stored in ventilated dry and cool place under ordinary conditions till sowing of next season crop. The mature dried seeds are distilled to obtain the essential oil. Hydro or steam distillation method is generally used for extraction of essential oil. It is better to use fresh seeds for more recovery of oil. On an average, the dry seeds yield 2.5-5 % oil and about 26% of fatty oils. The essential oil (2.5 to 5% in the dried fruits) is dominated by thymol (2-isopropy-5-methylphenol, 35 to 60%). Furthermore, a-pinene, p-cymene, limonene and d-terpinene have been found.

Dill (sowa) *(Anethum graveolens* L.)

Dill, a minor seed spice, belongs to the family Apiaceae and is grown for its leaves and seeds. Two types of dill viz. European dill (*Anethum graveolens* L.) and Indian dill or sowa (*Anethum sowa* Roxb) are under cultivation. European dill is mostly cultivated in England, Germany, Romania, Turkey, USA and the erstwhile USSR and Indian dill is mainly grown in Rajasthan, Madhya Pradesh, Gujarat, Maharashtra and Andhra Pradesh. In India, Rajasthan is main contributor in

dill production sharing about 48% of total dill production in India. Chittorgarh, Nimbahera, Jhalawar, Udaipur, Kota and Bundi are the main dill producing districts of Rajasthan. Dill seeds contain 2.5 to 3.5 per cent oil, which is very useful for human health and used as medicine in many ailments. Indian Dill (*Anethum sowa* Roxb.) and European Dill (*Anethum graveolens* L) are the two important oil yielding species of the genus *Anethum*, family Apiaceae.

Fig. 4.15: Dill plants

Fig. 4.15: Dill plants

Uses

Dill is mainly used, both whole as well as ground in condiment in soups, salads, processed meats, sausages. In various preparations, the green herb of dill is used as a flavouring agent. Ground seed is an important ingredient of seasoning. The residue of the seed after the extraction of the volatile oil is reported to contain about 16.8 per cent of fat and 15.1 per cent of protein which can be used as cattle feed. The amount of component responsible for the aroma (hexa hydrobenzofuran) in herbs varied between 4.5 and 7.5 mg/g DW. The essential oil is also used in the manufacturing of soaps.

Medicinal properties

Both seeds and oil are used in the preparation of various indigenous medicines. The dill water, which is comprising of essential oil, dill oil or its emulsion in water, is considered to be an aromatic, carminative especially useful in control of flatulence, colic pain, hyperacidity, vomiting, diarrhoea and hiccups due to indigestion in infants and children. Its application with turmeric powder prevents formation of ulcers and heals them quickly. Dill leaves, boiled in sesame oil, makes an excellent ointment for reducing swelling and pain of the joints. Seeds are effective in respiratory disorders likes colds, influenza and bronchitis. It is useful in inflammatory and painful conditions of piles for which it is used with vasa as fumigation therapy. It is very useful for women in delivery, for expulsion of placenta, and promote milk secretion.

Improved varieties: Ajmer Dill-1 and Ajmer Dill-2

Climate

Dill is cultivated as a *Rabi* or winter season crop for commercial seed production in India. However, at many places, it is also grown in rainy season as rain fed called early crop (sowing of seeds is done in late August to September) and harvested in winter season (December-January). It can resist frost to limited scale during vegetative stage. A dry climate with relatively high temperature is desirable during reproductive phase and seed maturity. Humid and cloudy environment favours incidence of diseases and pests, especially powdery mildew and aphid attack.

Land preparation

Dill or sowa can successfully be cultivated in all types of soils which are having good fertility status, carbon and water holding capacity except very light or sandy soils. The problematic soils like saline, alkali, sodic and acidic are also not suitable for its cultivation. For good harvest, loam, black loam and sandy loam soils with proper drainage facilities are most suitable for this crop. Dill, being hardy in nature with strong root system, does not require very fine tilth soil. However, soil should be prepared well into good tilth for better penetration of its roots and to hold sufficient quantity of water. The land is ploughed 2-3 times with harrow and cultivator and soil is pulverized and levelled before sowing for better germination. The field should be well levelled and divided into convenient size of beds for irrigated crop under check basin or flood systems. However, it is not required for the crop under micro-irrigation system. At last ploughing, apply quinolphos dust 1.5 % @ 20-25 kg/ha for the control of termites and soil insect-pest.

Cropping system

Dill crop can easily be grown as mixed or intercropping with other tall growing plants and fruit orchard.

The important cropping systems are as under:

- Green gram or Black gram in *Kharif* season followed by Dill in *Rabi* season
- Cluster-bean or Cowpea in *Kharif* season followed by Dill in *Rabi* season
- Green gram in *Kharif* season followed by Dill in *Rabi* season
- Maize or Peral-millet in *Kharif* season followed by Dill in *Rabi* season

In Zaid or summer, some vegetable crops like cluster bean, okra, and solanaceous crops can be included in the cropping system in organic matter rich and heavy soils but lighter soils should remain fallow or may have green manuring for maintain the sustainability.

Sowing time and method

Climate plays very important role in deciding sowing time of dill. However, it has been observed that crop sown during from 15th to 30th October results maximum yield and high volatile oil content in seeds. Delayed sowing results in to low seed yield with poor quality. Soil temperature from 21 to 27^{0}C gives better germination. Under rainfed conditions, sowing of dill should be done just after the end of rainy season *i.e.,* second week of September. Generally, it is sown by broadcasting the seeds evenly in the field. However, for facilitating intercultural operations, line sowing is preferred. Sowing of dill should be done at 1.5-2.0 cm deep while keeping 30-45 cm row to row spacing for Indian dill and 60 cm for European dill varieties and maintaining plant-to-plant spacing of 20 cm. Dill seeds germinate within 10 days after sowing under proper soil moisture conditions.

Seed rate

Application of proper quantity of seed is an essential agronomical practice for getting higher yield of dill. The seed rate varies with quality of the seed, variety and type of the crop grown. A seed rate of 6-8 kg/ha is sufficient for good crop. In broadcasting method of sowing and in unirrigated situation, seed requirement is relatively higher. To check the incidence of soil borne diseases, seed should be treated with Bavistin @ 2.5g/kg seed or with Trichoderma @ 4g/kg seed.

Manures and Fertilizers Dill crop is not generally manured by farmers though balance nutrition is required for good and healthy crop. About 6-8 tones well decomposed FYM should be mixed in the soil with the first ploughing at the time of land preparation. Besides 60 kg N and 30 kg P_2O_5 should be applied through fertilizers. In order to get higher yield of dill, it is advisable to apply 1/3rd of nitrogen and full dose of phosphorus as basal dose in the soil just before sowing and rest of the nitrogen should be applied in two split doses at 30 days after sowing and at flowering time as top dressing. Initially, if crop is poor, 1% solution of urea can be sprayed after 3 weeks of sowing.

Irrigation

The crop is sown under irrigated as well as rainfed conditions. It is grown as an irrigated crop in North India while in South India as a rainfed crop. Similarly, dill is generally grown as rain fed crop in black cotton soils whereas it is grown

as an irrigated crop in the light or sandy soil. In the situation of non-availability of sufficient moisture, at the time of sowing, a light irrigation can be given just after sowing for proper germination. At the time of flower initiation and seed development stage, sufficient soil moisture should be made available to the crop. In all 3-4 irrigations are sufficient to raise the crop. In the scenario of less availability water for irrigation the crops, micro irrigation system particularly drip system should be adopted, by which 40-50 % water can be saved.

Weed management

In India, dill crop is grown during *Rabi* season. Hence, presence of broad and narrow leaf weeds are common in the fields.

Weed management in the crop is very important as weed compete with the main crop for nutrient, water, light etc. Initial period of crop growth weed population is more harmful as compared to the presence of weeds in later period. Pre-sowing irrigation should be given to encourage growth of weeds before sowing of crop so that initially crop can be made weed free. Hence, after 8-10 days of pre-sowing irrigation, field should be ploughed so that the germinated weeds can be uprooted and the weed population is minimized. In order to reduce weed crop competition, it is advisable that first weeding and hoeing should be done 3-4 weeks after sowing. At the time of first weeding, thinning of plants may be done if required, to maintain the plant to plant distance of about 10 cm. Pre-emergence application of Pendimethalin @ 1 kg /ha after sowing or Oxadiargyl @ 0.075 kg/ha + one hand weeding at 45 DAS is good techniques for weed control. There should be sufficient moisture in the soil at the time of application of weedicides for enhancing effectiveness of weedicides. Eco-friendly approaches should also be adopted like, mulching, manual weeding/ hoeing and crop rotation to reduce weed population and improve quantity and quality of crop yield.

Pests and Diseases

Insect-Pests

Dill is frequently attacked with insect-pests of the locally important vegetable crops and other umbelliferae crops, but the damage is comparatively less. The crop is generally attacked by insects like aphid, cutworm and leaf eating caterpillars.

Aphid

It sucks tender part of the plant and flowers resulting in yellowing of crop and shrivelled grains. It can be controlled by spraying of Endosulfan (35 EC) 0.07%

@ 500-600 litres/ha solution, which is considered a relatively safer insecticide and should be used in evening when insect population is least

Leaf eating caterpillar

The caterpillar generally damages the leaves of the plant. It can be controlled by spraying of Endosulfan 0.05% once or twice depending on caterpillar population.

Diseases

Powdery mildew

Powdery mildew in dill is caused by fungus *Erysiphepolygoni*. The symptoms of the disease appear on all green plant parts including leaves, stem, and inflorescence as white powdery mass. The symptoms later on extended to other parts of plants including seeds which affect yield as well as quality of seeds.

The disease can be effectively controlled by sulphur dusting @ 20-25 kg/ha at the initial stage. Spraying with dinocap (0.1%) or wettable Sulphar (0.2 %) is also effective for the management of disease. First spray should be given on the appearances of disease and should be repeated at an interval of 10-15 days, if required, depending on the spread of disease.

Root rot

Root rot is cause by fungus *Fusarium* spp. The disease symptoms can appear in all growth stages but early vegetative growth stage is more affected with the disease. The leaves showing chlorosis initially become yellow and ultimately the plant dries and dies prematurely. The affected plant roots show browning and rotting. The disease can cause severe yield losses, if it appears early in the season.

Phytosanitary measures and seed treatment are important for controlling the disease. Seed treatment with carbendazim (2g/kg seed) or bio fungicide Trichoderma @ 4 g/kg seed are effective to control the disease.

Harvesting and Yield

Dill seed is grown for two purposes viz., for green vegetable and for grain. The timing of harvesting depends upon the purpose for which it is grown. The crop for green vegetable is harvested at 4-5 leaves stage 10-15 days after germination. Grain matures in 130-150 days and can be harvested in April-May. Harvesting of dill is usually done by cutting the plants with sickle 40 cm above ground level when seeds of main umbel turn brown. This crop can also be harvested mechanically by the use of rippers. It saves the labour and facilitate harvesting

in time. Delayed harvesting results in shattering of grains. Harvested bundles are kept on strings, ropes or racks under shade. Shade drying is good to retain the desirable grain colour and save the loss of volatile oil content of grains. Grains are then separated, either manually or by threshers, and dried. On average, the seed yield of dill is 12-15 quintal/hectare under irrigated conditions and 6-7 quintal/hectare under rainfed condition can be obtained.

Post-harvest management

The oil of dill can be extracted from both herbs and seeds. For the production of dill herb oil, fresh plants are chopped into 2-3 pieces and distilled immediately. Oil is extracted from dried fresh seeds through steam distillation. The quality of oil received from seeds is superior. An essential oil yield of 0.9 to 1.5% and 2.5 to 4% can be achieved from herbs and seeds respectively. The volatile oil and oleoresins, extracted from dill seed, has its demand in pharmaceutical, cosmetics and food industry.

Activities

Visit any seed spice field crops

Material required: Pen, pencil, notebook

Procedure: Make the following observations during the visit

- Conditions under which it cultivated
- Name of Crop and variety
- Spacing adopted
- Approximate height of the tree
- Time of flowering, Fruiting and harvesting.

Check Your Progress

A. Fill in the Blanks

1. Coriander is seed spice crop and a member of family ……
2. Pant Haritma is important variety of coriander for which state ……
3. Seed rate for cumin is …… per hectare.
4. Hisar Swarup important variety of ……
5. Trigonella corniculata is known as ……
6. Seed should be treated with bavistin or thiram @ …… seed.
7. Nigella crop is very sensitive to ……at any growth stage.

8. The properly cleaned ajwain seeds are stored with an initial moisture level of ……

9. Indian dill botanically known as ……

10. Seed rate of dill ……is sufficient for good crop.

B. Multiple Choice Questions

1) Coriander is a tropical crop and can be grown throughout the year except

a) September- October

b) December- January

c) March-May

d) June- July

2) Application of sulphur dust is also effective against powdery mildew control in coriander

a) 15 kg/ha

b) 25kg/ha

c) 35 kg/ha

d) 45kg/ha

3) The somatic chromosome number of cumin

a) 2n=14

b) 2n=16

c) 2n=18

d) None of the above

4) Alternaria blight disease resistant/tolerant varieties of fennel

a) RF-143

b) RF-101

c) AF-2

d) AF-1

5) Rajendra Kranti is a variety of

a) Fenugreek

b) Dill

c) Fennel

d) Coriander

6) Being a leguminous crop Fenugreek fixes _____nitrogen per hectare per year from the atmosphere into the soil.

a) 150 kg

b) 283 kg

c) 245 kg

d) 380 kg

7) Nigella an important annual herbaceous plant belonging to family of____.

a) Fabaceae

b) Apiaceae

c) Ranunculacea

d) None of the above

8) Dill seeds contain _____per cent oil,

a) 2.5 to 3.5

b) 3.5-45

c) 4.5-5.5

d) 5.5-6.5

C. Match the Columns

A	**B**
1. Coriander	a) Fabaceae
2. Wilt	b) Fenugreek
3. Fennel	*c) Fusarium oxysporiurnf*
4. Fenugreek	*d) Bemisia tabaci*
5.Hisar Sonali	e) Swathi
6. White fly	f) Mediterranean and Southern European
7.Seed treatment	g) Nigella

8. Minor seed spice	h) Captan

D. Subjective Questions

1) Describe the cultivation practices of coriander under following heads.
   - State-wise recommended varieties
   - Climate and soil,
   - Land preparation
   - Sowing time and Seed rate
2) Describe the weed management of cumin.
3) Briefly explain the propagation of fennel.
4) Describe the Insect- pest of fenugreek.
5) Write a brief note on the processing and post-harvesting management of fenugreek.
6) Mention the major insect and disease affecting nigella.
7) List the state- wise improved varieties of fennel.

Module 5
Tree and Pod Spices Cultivation

Module Overview

This module provides an in-depth exploration of the cultivation practices for major tree and pod spices such as cardamom, cinnamon, nutmeg, and cloves. This module covers essential topics including site selection, planting techniques, crop management, pest and disease control, and post-harvest processing to ensure high-quality spice production. It is designed to equip learners with practical knowledge and skills for sustainable and profitable spice cultivation.

Learning Outcomes

After completing this module, you will be able to:

- Demonstrate best practices in the cultivation of pod spices
- Cultivate black pepper, focusing on its growing conditions, support structures, and care techniques.

Module Structure

- Session 1: Cultivation of Tree Spices
- Session 2: Cultivate Pod Spices
- Session 3: Cultivate Black Pepper

Session 1: Cultivation of Tree Spices

Cinnamon

Scientific Name: *Cinnamomum verum* Presl.

Family: Lauraceae

Part used: Bark

Indian Names: Hindi: Dalchini, Darchini Bengali: Dalchini Gujarati: Dalchini Kannada: Dalchini Malayalam: Karuvapatta Marathi: Dalchini Oriya: Dalchini Punjabi: Dalchini Sanskrit: Darushila Tamil: Karuvapattai, Sannalavangapattai Urdu: Dalchini

Cinnamon is the known for its dried bark which has a sweet and agreeable taste. The bark, either in the form of small pieces or powder, is used as spice or condiment. The essential oil obtained from leaf is used in the manufacture of perfumes, soaps, face creams, hair oils and tooth pastes. In addition, the

cinnamon available in the market comes from other sources like C. *cassia,* (True cassia or Chinese cassia) and *C.* tamala (Indian cassia) and C. *burmanni,* (Indonesian cassia). One can distinguish these two with the following characters

Characters	**Cinnamon bark**	**Cassia Bark**
Nature of bark	Thin and smooth	Coarse and thick
Colour of bark powder	Tan	Reddish brown
Aroma	Less intense	More intense
Essential oil content	Less (0.5-2 %)	High (1-4.5 %)
Primary constituent in the leaf oil	Eugenol	Cinnamaldehyde
Flavour	Good	Not so delicate

Fig. 5.1: Cinnamon and Cassia barks

Origin and Distribution

Cinnamon is believed to have originated in Sri Lanka and the Southern part of West Coast of India. Sri Lanka is the other major producer of cinnamon and Seychelles Island is the next important producer. The cultivated type, *C. verum*, is found in the lower altitudes of the Western Ghats of Kerala including Kannur, Kozhikode and Kottayam districts, the lower Nilgiris of Tamil Nadu and the coastal districts of South Karnataka.

Uses

Cinnamon bark is a popular spice with a delicate fragrance and a sweet taste. It has antifungal properties. It is widely used in flavouring confectionary, beverages, pharmaceuticals and cosmetics. It helps in treatment of diabetics as it aids digestion of sugar. It can keep nausea and vomiting in check. The cinnamon leaf oil is also used in cosmetics and perfumery.

Climate and Soil

Cinnamon is a hardy plant and grows well under different climatic conditions. It thrives well under topical evergreen forests of Western Ghats. Ideal climatic factors suitable for cinnamon include:

- Elevation: 1000 m above MSL.
- Annual rainfall: 150-250 cm
- Average temperature: 27^{o}C

Cinnamon grows well in wide range of soils. Sandy loam soils with rich humus give superior quality bark. Sandy soils generally result in higher yield. Water logged soils are not suitable for cinnamon.

Varieties

Some of the popular types of cinnamon cultivated in Sri Lanka and India are Sweet Cinnamon, Honey Cinnamon, Camphor Cinnamon, Snake Cinnamon and Astringent Cinnamon. Improved varieties like Navashree and Nithyashree selections were released from IISR, Calicut. Other improved varieties are YCD-1, Konkan Tej and Sugandhini.

Cultivation

Propagation

Cinnamon is commonly propagated by seeds. Cinnamon fruits ripen in May-June which are collected from the mother trees and separated from the adhering pulp. They are shade dried and sown immediately. Seeds have short viability. Fresh seeds are sown at a distance of 15 cm apart on raised nursery beds that are 90–100 cm wide, 15 cm tall, and of convenient length. Seeds can be sown in polyethylene bags filled with a potting mixture consisting of soil, farm yard manure (FYM) and sand (2:1:1). Beds or bags are regularly watered. The seeds require about 15-20 days for germination. The seedlings can be transplanted into polybags 3-4 months after germination. Seedlings will be ready for field planting in about 10-12 month.

Fig.5.2: Cinnamon seedlings

Alternatively, cinnamon can be multiplied vegetatively by cuttings and air layers. The hard wood cuttings will give 45 % rooting with exogenous application of IBA 2500 ppm. Air layering will give 85 % rooting. The ideal period of layering is from July to September.

Land preparation and planting

Cinnamon is planted by opening 50 x 50 x 50 cm pits with a 3 m x 3 m spacing. Five seedlings are placed in each of the pits which are filled with compost and topsoil. Planting is preferably done during June-July using 10-12 month old seedlings. Providing partial shade in the initial years will help in rapid growth and development of healthy cinnamon plants. It can also be planted as a mixed crop in the interspaces of coconut or arecanut.

Manures and Fertilizers

Recommended dose of nutrients for cinnamon is 20 kg of FYM, 20 g of N, 20g of $P_2 0_5$ and 25 g of $K_2 0$ per pit in the first year. The dosage is annually increased and 50 kg FYM/ compost, 200 g N, 180 g $P_2 0_5$ and 200 g $K_2 0$ is applied to plants of 10 years and above. The fertilizers are applied twice, once in May - June and second in September - November.

Irrigation

Cinnamon is cultivated as a rainfed crop generally. However, regular watering is done during drier months in the initial 2-3 years.

Inter-cultivation

Inter-cultivation include digging the soil around the plants to loosen the soil during August – September and two weedings during June - July and October - November. Soil moisture conservation can be done by mulching the soil around the plant with dry leaves or grass and then covering them with the soil.

Pruning

The seedlings grow to a height of around 2m in two years. To encourage side shoots, the young plants are cut at a height of 15 cm from the ground. This process is called coppicing.

Fig 5.3 Cinnamon plantation

Harvesting and Curing

The plants will be ready for cutting the shoots in about 3 years after planting. Harvesting may often be done twice a year - once in May and again in November. Based on the flow of sap between the wood and bark, the appropriate time for cutting the shoots for peeling is determined. To assess the proper stage, make a trial cut on the stem using a sharp knife. If the bark separates readily, the cutting is taken up. Stems with a diameter of 2.0 to 2.5 cm and length of 1.5 to 2.0 m are cut during early morning and branches and leaves are separated.

Once the stems are cut, cinnamon processing involves peeling, rolling, piping drying and grading.

Preparation of shoot for peeling: The outer brown rough bark is scrapped off using a curved brass or stainless knife. Then the stem is rubbed vigorously with a brass rod to loosen the soft greenish bark.

Peeling: Two cut are given around the stem at a distance of 30 cm and two longitudinal slits given on the opposite sides with a sharp knife. By using the knife, the two halves of the bark are carefully removed.

Rolling: After scrapping, the barks are sorted based on their thickness into different grades. They are rolled to form pipes by placing the smaller ones above the larger ones.

Fig 5.4: Quills of cinnamon

Drying: Soon after piping, they are allowed to dry. These are dried in the shade for a day to help in the slight fermentation and kept in sunlight for 3-4 days.

Grading: The quality of the quills is graded from "00000" (the finest quality) to "0" (the coarse quality). The small interior pieces of bark are known as featherings and the small and broken portions of the bark, which are left over after making the quills, are known as quilling. When peeling is not possible, the bark is scrapped off, instead of peeling which is known as chips.

Yield

During the first year of harvesting, about 65-125 kg of quills can be obtained from hectare. When the plantation is of 10 years age, a yield of 225-300 kg of quills per hectare can be obtained.

Leaf oil from cinnamon

The leaves separated from the stem during the harvesting of cinnamon can be used for extraction of leaf oil through steam distillation. The leaves yield 0.5-0.7% oil, which contains eugenol and cinnamic aldehyde.

Pests and Diseases

Insects-Pests

Cinnamon butterfly (*Chilasa clytia*): The caterpillars feed on tender and slightly mature leaves and in severe cases of infestation, only midrib is left. Insect can be controlled by spraying quinalphos 0.05 % on the foliage.

Leaf miner (*Conopomorha civica*): Larva feed in between the lower and upper epidermis of tender leaves which results in blister like symptoms. The damaged

area dries and large holes are seen on leaves. Insect can be controlled by spraying quinalphos 0.05 % on the foliage.

Diseases

Leaf spot and dieback (*Colletotrichum gloeosporioides*): Small brown spot appear on leaves which enlarge resulting drying of leaves. Later, it spreads to stem resulting in die back. It can be controlled by spraying Bordeaux mixture @ 1.0 %

Grey leaf blight (*Pestalotiopsis palmarum*): Small brown spots on the leaves later turn to grey with brown border. Spraying Bordeaux mixture @ 1.0 % can control this disease.

Clove

Botanical Name: *Syzygium aromaticum*

Family: Myrtaceae

Commercial Part: Unopened flower bud

Indian Names: Hindi: Laung Bengali: Lawang Gujarati: Lavang Kannada: Lavanga Malayalam: Grambu Marathi: Luvang Oriya: Labang Punjabi: Laung Sanskrit: Lavanga Tamil: Kirambu, Lavangam Telugu: Lavangalu Urdu: Laung

Clove is another important tree spice. The clove used as spice is the mature but unopened dried flower bud of *Syzygium aromaticum* which is an evergreen tree. The name of this spice originates from the French word meaning 'cloy', meaning nail. Clove is valued both as a spice and for its volatile oil. The volatile oil extracted from the dry clove buds contains 80-90 % eugenol.

Fig 5.5: Clove flower bud

Fig. 5.6: Dried clove buds

Uses

Clove, either whole or in ground form, is mainly used for culinary purposes and as a flavouring agent in food industry. In Indonesia, cloves are used in production of 'kretek' cigarettes. Clove oil is used in medicine especially in dentistry, oral and pharyngeal treatments due to its antiseptic and antibiotic properties. It is also used in preparation of toothpastes, mouthwashes, soaps and perfumes.

Origin and Distribution

Clove is indigenous to Indonesia particularly the Moluccas Islands. Tanzania, Pemba, Madagascar and Indonesia are the major clove producing countries in the world. In India, clove was introduced in 1800 AD by British. Clove is presently cultivated in the southern states of Tamil Nadu, Kerala and Karnataka.

Climate and Soil

Clove grows well under warm and humid climate. Following are the climatic conditions suitable for clove cultivation:

The annual rainfall -150-300 cm

Relative humidity - 70% and above

Altitude – From sea level up to 700-900 m

Temperature - 20-32°C.

While selecting the location for cultivation of clove, windy locations should be avoided as clove cannot withstand strong winds. It requires partial shade during the initial period of plantation for its good growth.

Clove can be grown on deep red loam, black or lateritic soils rich in humus, with a pH between 4.0 and 5.6. However, sandy soils and water-logged conditions are not suitable for its cultivation. It can be grown both on hill slopes and plains.

Varieties

Clove plantations in India probably have originated from a few seedlings obtained from Mauritius. There are no named cultivars in clove. They are recognized on the basis of the places of their cultivation. Penang cloves, which are large, plump and bright reddish, are considered the best in appearance, followed by the Zaniibar and Madagascar types. Burliar-1 is one of the two high yielding progenies selected in Tamil Nadu. The other is from Odetham estate.

Cultivation

Propagation

Clove is propagated through seeds. The ripe fruits of clove is called the 'mother of clove'. The ripe fruits (i.e. mother of clove) are harvested from selected regular bearing mother trees and from them seeds are extracted. These seeds have very short viability. Hence, they should be sown as early as possible. Fresh seeds are sown in raised nursery beds as explained for cinnamon. The seeds take about two weeks for germination and it is completed in 40 days. Thereafter, seedlings of 50 cm height are transferred to polythene bags (30 cm x 15 cm) containing a mixture of red soil and manure. Seedlings in the nursery are provided with proper shade and water. About two years old seedlings can be planted in the main field.

Land preparation and planting

About one or two months prior to planting, pits of 60-75 cm^3 are dug at a spacing of 6 m x 6 m. The spacing can be modified suitably if planted as an intercrop. Topsoil and FYM are used to fill the pits. The best time to plant is between June and August. Clove favours partial shade. Hence, it suits best for mixed-cropping in older coffee, coconut, and arecanut plantations. If clove is grown as a sole crop, shade trees such as *Acacia sp.*, *Albizia* sp. or Banana can be established as shade trees prior to clove planting.

Manures and Fertilizers

About 15 kg of FYM or compost per plant is applied before planting and every year along with inorganic fertilizers. The recommended dose of inorganic fertilizer is 20:18:50 g NPK per plant after first year, and gradually increased to 200:180:150 g NPK per plant after 10 years. The manures and fertilizers can be applied around the plant, about 1m away from the base. Manuring is done in two splits: During May- June, organic manure along with a half dose of fertilizers and during September-October, the remaining quantity of fertilizers may be given.

Mulching and Weeding

Mulching the soil around the base of the tree during summer to conserve soil moisture and to reduce weed growth.

Irrigation

In the first 3-4 years of clove plantation, care should be taken particularly during the summer months to provide protective irrigations. Drip irrigation with around eight litres of water per plant per day, will be desirable.

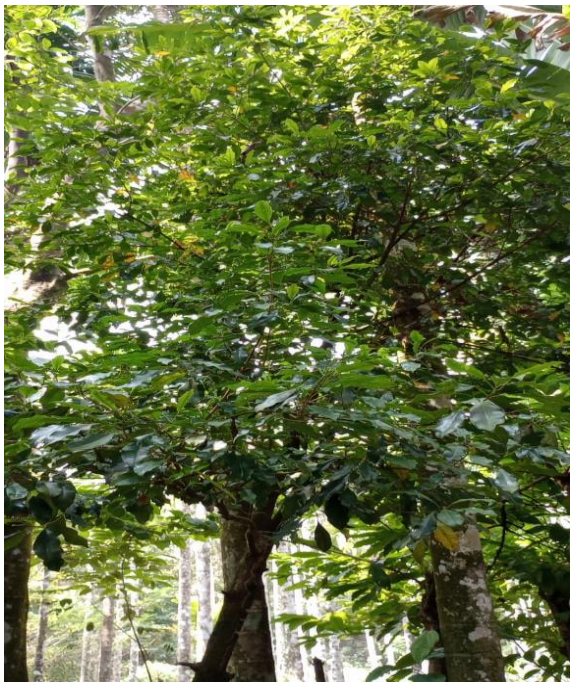


Fig. 5.7: Grown clove tree

Fig. 5.8: Harvested clove buds

Harvesting and Yield

Clove trees start flowering from 4-6 years of their planting. But an economic yield can be obtained only 18-20 years after planting. The plantation has a lifespan of 80 years or more. In the plains, the flowering season lasts from September to October whereas in the high altitudes, it lasts from December to January. The economical part, i.e. flower buds, are produced on the terminal shoots of the branches. The buds are harvested when they turn pink in colour and are less than 2 cm long before they open. The entire inflorescence is harvested when the buds have reached their full size. If the flower buds open, their spice value lost. The buds are removed from the flower bunch and then collected in separate heaps during which sorting is done to separate over mature or opened flower buds and fallen flowers. Drying is undertaken immediately after the buds are separated from the clusters. In bright sunny weather, drying may take four to five days. When the base of the bud is dark brown and the remainder of the bud is light brown, the bud is said to be dried.

On an average, about 2 kg of flower buds per tree per year (500 kg/ha) can be obtained. About 11,000-15,000 dried cloves are required to make one kilogram. Cloves are packed in double layered gunny or HDPE sacks of 50-60 kg capacity.

Processing

The appearance, size, content and aromatic characteristics of its volatile oil are the factors which decide the quality of the dried spice.

Grading

Bold size cloves with a bright, uniform and reddish-brown colour are considered to be of superior grade. Whole cloves are graded as special (handpicked), Grade-2, Grade-3, Ground (powdered) cloves, while the defective cloves are named as *Khoker cloves,* Headless cloves, Mother cloves, Eextraneous matter, etc.

Pests and Diseases

Insects-Pests

Stem borer (*Sahyadrassus malabaricus*): The stem borer infests the main stem of young trees at the basal region. The larva of the pest girdles the stem and bores downward into it. Indoxicarb 0.15 % can be sprayed around the damaged area. Quinalphos 25 EC @ 1 ml/lit in to the bore hole and plug it.

Scale insects: Infestation is seen on young leaves. Due to sucking of the sap leaves show yellow spots. They can be controlled by spraying 0.05 % dimethoate.

Diseases

Leaf spot, twig blight and flower shedding (*Colletotrichum gloeosporioides*): When the flowers are affected, there is heavy shedding of flowers and the losses are huge. With the initiation of the disease the tree is sprayed with Bordeaux mixture (4:4:50) or mancozeb (0.25%) and repeated at 14 days interval particularly in rainy season.

Sudden death (*Valsa eugeniae*): It is a one of the serious diseases of clove. On mature trees, slight chlorosis occurs on the leaves which results in a sudden and rapid leaf fall followed by wilting of the plants. The affected plants have to be destroyed.

Leaf rot (*Cylindrocladium quinquiseptatum*): It is noticed in the nurseries as well as in the main field both at young and mature stages. Infection starts as dark spots at the leaf margin. Rotting may be in the whole leaf or at the tip resulting in defoliation. Seedling and young plants can be sprayed with systemic fungicides viz., Carbendazim 0.1%

Nutmeg

Botanical Name: *Myristica fragrans*

Family: Myristicaceae

Commercial Part: Seed and aril

Hindi: Jaiphal Bengali: Jaiphal Gujarati: Jaiphal Kannada: Jayikai Kashmiri: Zaaphal Malayalam: Jathikka Marathi: Jaiphal Oriya: Jaiphala Punjabi: Jaiphal Sanskrit: Jatiphala Tamil: Jathikai Telugu: Jajikai Urdu: Jaiphal

Nutmeg is dioicous tree spice which yields two types of spices viz., the hard and brown kernel enclosed in a thin brittle shell which is called nutmeg and the scarlet coloured aril surrounding the shell which is called mace. Volatile oil of nutmeg contains sabinene (30-50%) and alpha-pinene (10-20 %) and mace oil is similar to nutmeg oil. The nutmeg oil also contains 4 % myristicin which is responsible for hallucination effect.

Fig. 5.9: Bearing nutmeg tree

Fig. 5.10: Nutmeg fruits

Fig. 5.11: Nutmeg fruit, mace and nut

Uses

Both nutmeg and mace are used as spice particularly in sweet foods. Nutmeg oleoresin is used in meat products, soups, sauces, baked foods, confectionaries, puddings, seasoning of meat and vegetable. The fleshy rind of the fruit is processed into candies and pickles. Excessive doses have a narcotic effect. Nutmeg oil is also used in cosmetics and toiletries.

Origin and Distribution

Nutmeg has its origin in Moluccas islands of Indonesia. Malaysia is the major producer of nutmeg in the world. Other countries producing nutmeg are Indonesia, Grenada, Sri Lanka, India, Tanzania, Mauritius, Reunion, Trinidad and Tobago and China. In India, nutmeg is presently grown in Kerala, Karnataka and Andaman and Nicobar Islands. The annual production of this spice is 15,595 metric tonnes and it is grown across an area of 24,430 hectares.

Soil and Climate

Nutmeg prefers warm, humid conditions. Following are the climatic conditions suitable for clove cultivation:

Annual rainfall: 150 cm to 250 cm

Temperature: 25-35°C

Altitude: From Sea level up to 1300 m.

Partial shade is beneficial in the early stages of growth. Ideal soils for cultivation of nutmeg are clay loam, sandy loam and red laterite soils which are rich in humus. Dry climate and waterlogged conditions are not suitable for nutmeg.

Varieties

The nutmeg traded in the world are of two types viz., West India and East India types. Nutmeg grown in the Islands of Grenada and Trinidad are called the West Indian variety while those coming from South East Asia are called East Indian nutmegs which are highly aromatic and superior compared the former variety.

The improved varieties of Nutmeg released in India are: Konkan Sugandha, Konkan Swad, Konkan Shrimanti and IISR- Vishwasree.

Cultivation

Propagation

Nutmeg is propagated by seeds as well as vegetatively by budding and grafting.

Propagation by seeds

For raising seedlings, seeds are collected from selected mother trees when the fruits are ripe and split open. Some of the desirable characters of a mother tree are

- fruit weight of 30 g,
- nut weight of 7 g,
- mace weight of 1 g, and
- yield of more than 10,000 fruits per tree per year.

The seeds lose their viability quickly and hence should be sown immediately. The seeds are sown within three days after extraction in nursery beds or polybags. The seedlings at 2- leaf stage can be transferred to polythene bags. Seedlings of 12 to 18 months are ready for planting in the main field.

Vegetative propagation

Being a dioecious crop, one of the major issues in growing nutmeg from seed is the segregation of male and female plants, which results in about 50% of the trees being unproductive. Besides, they have long juvenile period. Vegetative propagation is the best way to overcome this problem.

Epicotyl grafting*:* Grafting is done on 20 days old healthy seedling sprouts as root stock using a pencil thick scion from a female tree. Graft joint is tied with a polythene strip and the whole plant is placed in a polybag filled with a potting mixture. Graft is covered with a polythene tube till the scion sprouts, to ensure high humidity for better graft union. Suitable time for grafting is August – September. Seedlings of *Myristica malbaricum* a wild type can also be used as rootstock.

Fig. 5.12: Nutmeg budded plants

Top working

Seedling nutmeg trees flower after 7-8 years. The male tree can be identified only after they flower. Generally, there will be 50 percent male in a seedling progeny. One male tree is sufficient for 20 female trees for pollination. Other unproductive male trees can be converted to female trees by top working. Male trees are cut about 30 cm above the ground level in May, the cut end is smeared with Bordeaux paste. The newly emerged shoots are wedge grafted using scions from orthotropic shoots (lateral branches) secured in place firmly with a polythene strip. Grafted shoots are covered with a polythene tube as done in epicotyls grafting. After the graft is successful, other shoots are removed from the main trunk. We can get yield from the top worked trees in 3 years after top working.

Land preparation and planting

An 8 m x 8 m spacing is recommended when planting nutmeg as the sole crop. About 15 days before planting, pits of 0.75 m^3 are opened and filled with organic manure and top soil. The plants need to be shaded by planting banana or glyricidia to prevent sun scorching in the early stages. The time of planting is the beginning of the rainy season.

Nutmeg is commonly grown as a mixed crop in the coconut and arecanut gardens, where the sufficient light is available. Between four coconut trees, one

nutmeg can be planted, while in arecanut, it can be planted in every alternate row in zig-zag manner. A male graft should be planted for every 20 female grafts.

Manures and Fertilizers:

Farm Yard Manure is applied at 10 kg per pit and gradually increases to 50 kg FYM per plant when trees are 15 years old. A dose of 20 g N, 18 g P_20_5, and 50 g K_20 is applied to each plant one year after planting. The dosage gradually increases. The recommendation for a 15 year old tree is 500 g, 250 g and 1000 g of N: P_20_5 and K_20. The manure is applied in shallow trenches about 50 cm away from the base of the tree during May-June and September-October.

Irrigation and Inter-culture

Regular weeding and irrigation will ensure proper growth and yield of nutmeg. Irrigation in summer months is essential in dry areas. In lighter soils, the plant basins are mulched with dry leaves to conserve moisture.

Harvesting and Yield

The nutmeg trees start bearing from the sixth year onwards but the economic yield is obtained after 15 or 20 years. The fruits require about 6-9 months for maturity. June-August or December-May are the peak periods of harvest. When the pericarp splits open, her fruits are ready for harvesting. The fruits are collected, split open and the nut with mace is separated. The nut and mace are meticulously separated. In a drying yard, the nut and mace are dried separately in the sun. The mace needs to be dried for around 10-15 days and the nuts for 4-8 weeks till the kernel rattles within the shell.

Trees yield about 1000-2000 at the age of 15 years. The yield of dried nutmeg and mace will be around 1000 kg of nutmeg and 200 kg of mace per hectare respectively.

Grading

The dried nutmegs are graded manually based on their weight, shape and colour.

Pests and Diseases

Insects-Pests

Scale insects: Different types of scale insects such as black scales (*Saissetia nigra*) and white scales (*Pseudaulacaspis cockerelli)* infest nutmeg leaves and suck the sap. Scales can be controlled by spraying Dimethoate 0.05 % or quinalophos 0.025%**.**

Diseases

Thread blight (*Marasmius pulcherima*): The mycelia strands cause blight of stem and leaves. Threads of mycelium hold up the detached leaves giving appearance of bird's nest. The disease can be managed by proper phyto-sanitation and spraying of Bordeaux mixture 1%.

Fruit rot (*Diplodia natalensis and Phytophthora* sp.): Immature fruits split and rotting of mace is seen. Spraying of Bordeaux mixture @1% when the fruits are at half mature can reduce the incidence.

All spice

Botanical Name: *Pimenta dioica*

Family: Myrtaceae

Commercial Part: Fruit & Seed

Indian names: *Allspice,*

Kannada: Gandamenasu Malayalam: Sarvasugandhi Tamil: Sarvasukanthi

Allspice, also known as Pimenta, Pimento and Jamaica Pepper, is a minor dioecious tree spice. The economical part of allspice is the dried immature fruit. The leaves and dried fruits possess the characteristic flavour and aroma of cloves, nutmeg and cinnamon, hence, it is probably given the name all spice.

Fig. 5.13: Allspice flower

Fig 5.14: Allspice berries

The characteristic flavour of allspice is due to the essential oil (3-4.5%), present mainly in the outer skin. This essential oil contains primarily eugenol (65-80%) and methyl eugenol (8%). The dried berries are used for flavouring ketchups, soups, sauces, pickles, sausages, fish dishes and puddings. They are also used for flavouring wines.

Origin and Distribution

Allspice is native of West Indies and tropical Central America. Jamaica is the major producer of all spice which grows semi-wild in in West Indies. Other growing regions of allspice are Mexico, Honduras, Guatemala, Cuba and Costa Rica. In India, allspice is cultivated to a limited extent in West Bengal, Bihar and Orissa, Kerala, Karnataka and Tamil Nadu.

Soil and Climate

Climatic elements required for all spice are as follows:

Annual rainfall:100 to 200 cm or more

Altitude: sea level to 1000 m above MSL

Mean monthly temperature: 27°C

The allspice does not fruit in plains. At higher elevations, with cooler and wet climate, the incidence of rust disease is severe. The plant can be grown on a wide range of soils including poor soils with good drainage. It is not suited to red soils with inadequate moisture.

Varieties

There are no named varieties of allspice in India. Few local types are available in Tamil Nadu.

Propagation

Allspice is mainly propagated through seeds. High yielding and regular bearing trees of all spice are identified for seed collection. The ripe fruits are collected from such trees and are soaked in water overnight. Next day, they are rubbed to extract seeds. The extracted seeds are then dried in shade. Since the seeds have short viability, they should be sown immediately. The seeds are sown in nursery beds or polyethylene bags. After sowing, the nursery beds are mulched with dry leaves to hasten germination. Watering is done on a daily basis. Germination takes place between 10 and 15 days after sowing.

Fig. 5.15: Seedlings ready for planting

Land preparation and planting

The land preparation begins by removing the unwanted vegetation. In undulated land, contour planting is recommended. Pits of 60 cm^3 are dug at the spacing of 6m x 6m and they are filled with FYM or compost and top soil

Seedlings of 6–10-month-old with 25-30 cm height are used for field planting. Allspice is structurally hermaphrodite, but, functionally dioecious. Three seedlings are planted in each pit. Male plants are retained at the ratio of one male for every 8 female plants for proper pollination. Allspice can also be grown as an intercrop in arecanut, coconut and coffee plantations.

Manures and Fertilizers

An ad-hoc fertilizer schedule of 10 kg FYM along with 20:18:50 g of N, P_20_5 and K_20 during the first year is recommended since there is not much research work on this aspect. The dose is gradually increased such that a 15 year old tree is given 50 kg FYM and 300:250:750 g of N, P_20_5 and K_20. The ideal time for fertilizer application is May-June and September-October.

Irrigation

The plants are watered during the dry months in the early stages of growth.

Weeding

As the crop is widely spaced, weed problems are common, especially in the early stages. By regular weeding and mulching, the base of plants should be kept clean.

Fig 5.16: Bearing tree

Fig. 5.17: Bunches with berries

Harvesting and Yield

It takes 5-6 years for the allspice plants for flowering. The male trees flower early compared to the female. The flowering time in India is March to June. The fruits are ready for harvest 3-4 months after flowering. The ideal stage of harvesting allspice is when they are green, fully matured but not ripe. The berries are produced in clusters. And these clusters are manually collected by climbing the tree using ladder. The ripe berries are separated from the green after harvesting.

Fig. 5.18: Allspice dried berries

The berries are dried by spreading them in the sun and turned over regularly for uniform drying. Drying takes 8-10 days. Good quality dried berries are bright brown in colour.

Yield

A fully grown tree yields 20-25 kg of dry berries per year.

Grades/types

There are four major grades/types of allspice in the world trade. They are, Mexican, Guatemala, Honduras and Jamican pimenta. Jamaican allspice has the best appearance, aroma, flavour and volatile oil content (4.0-4.5%).

Pests and Diseases

Insects-Pests

Tea mosquito bug: Insect infests tender shoots and leaves. The infestation results in drying of the tender shoots and formation of necrotic spots on the leaves. Spraying with quinalphos (0.05%) will control the pest.

Diseases

Leaf rust: It is the most serious disease which results in the defoliation of the young leaves. To control the disease, the young leaves and inflorescences are sprayed with Dithane M-45.

Tamarind

Botanical Name: *Tamarindus indica* L.

Family: Cesalpiniaceae

Commercial Part: Pods

Indian Names: Asamese: Teteli, Bengali: Tentul, Gujarati: Amli, Kannada: Hunisehuli, Kashmiri: Tambari, Malayalam: Puli, Valanpuli, Hindi: Imli, Oriya: Dalima, Punjabi: Imli, Sanskrit: Tintiri, Amli, Tamil: Puli, Telugu: Chintapandu

Tamarind is a tropical fruit tree used primarily for its fruits that contain a sweet and sour pulp (mesocarp of the fruit), which are consumed fresh or processed. Tamarind pulp used as a seasoning or spice in several culinary preparations. The sour taste of tamarind pulp is due to tartaric acid. The pulp is also used in medicine and as a metal polish. Seeds are processed for non-food uses. The tamarind kernel powder is extensively used for its sizing properties in textile, confectionary, cosmetics and pharmaceutical industries.

		
Fig 5.19: Flower	*Fig.* 5.20: Fruit (Pod)	*Fig.* 5.21: Pulp

Origin and Distribution

Tamarind has originated in Madagascar and is now extensively cultivated in India, Myanmar, Bangladesh, Malaysia, Sri Lanka, Thailand, and several African, Central American and South American countries. In India, it is chiefly grown in Karnataka, Tamil Nadu, Kerala and Andhra Pradesh. The total area under Tamarind in India is about 48 thousand hectares with estimated annual production of 201 thousand tons.

Soil and Climate

The following are the climatic requirements for tamarind cultivation:

Temperature: Maximum of 36-47.5^0 C and Minimum of 0-17.5^0 C.

Rainfall: 750-1900 mm.

Altitude: up to 100 m above MSL.

Tamarind is adapted to a wide range of climatic conditions. Tamarind grown under the wet tropics does not flower. In fact, dry weather is important for flower initiation and heavy rains during flowering affect the productivity. The tamarind tree can grow in a wide range of soils and has no specific soil requirement. It can be planted even on poor degraded, eroded, gravelly, saline and alkaline soils. Productivity is higher in red loamy, deep well drained soils.

Varieties

Important varieties in India are PKM 1, Urigam, Hunsur, Tumkur, Prathisthan, DTS 1, Yogeshwari.

Propagation and Nursery Management

Tamarind can be propagated by seed or grafting. However, commonly practiced method is by wedge grafting.

Nursery

Freshly harvested seeds separated from the pulp and are sown in nursery beds in March – April. Seed germination can be enhanced by soaking of seeds in 10 per cent cow urine or in cow dung solution (500 g in 10 litres of water) for 24 hours. Two year old seedlings are transplanted to the main field. However, these seedlings will not resemble the parent plants.

Vegetative propagation

Commercially, tamarind is propagated by softwood or wedge grafting. One year old seedlings are used as rootstocks. The dormant, shoots as scions, are used as scions. Ideal time for grafting is in the month of March- April.

Fig. 5.22: Tamarind nursery

Fig. 5.23: Grafted plants

Planting

One year old grafted plants are planted at a spacing of 10 m ×10 m. Pits of 1×1×1 m are dug in the month of May-June and filled with 15 kg FYM along with loose soil. The ideal time for planting is June-July. It should be ensured that graft union is at least 10–20cm above the ground level while planting. Plants are be staked and shoots arising from rootstock need to be removed regularly.

Irrigation

Tamarind is a drought tolerant tree and hence, mostly grown as a rainfed crop. However, regular watering is essential for the establishment during the initial 2 to 3 years. In dry areas, the use of water conservation techniques during the rainy season should be adopted as it encourages subsequent growth and fruiting.

Training and Pruning

Initial training of young plants during the initial years is essential for the development of framework of the trees. Young trees should be trained to allow 3-

5 well-spaced branches to develop into the main scaffold structure of the tree. Bearing trees require very little pruning other than pruning to remove dead, weak and diseased branches and water sprouts.

Fig. 5.24: Bearing tree

Manures and Fertilizers

Tamarind trees fruit well even without fertilizer application, due to their deep and extensive root system. It is recommended to apply 40:20:40 g of NPK per tree per year along with 25 kg of FYM per plant after first year to be increase to 400:200:400 g of NPK after 10 years.

Intercropping

Being a widely spaced crop, tamarind permits intercropping with a variety of annual crops. Vegetables and legumes can be grown during the rainy season in the interspaces in the first three to six years.

Harvesting

In general, flowering and fruiting of tamarind takes place in the dry season. An extended spell of dry weather may be essential for fruit development. The period from flowering to pod ripening is 8-10 months. Plants starts bearing from 4th year of planting and the economic yield will be obtained from10th year. Pods are harvested in March – April.

Fig. 5.25: Pods ready for harvest

Pests and Diseases

Insects-Pests

Fruit Borer: The larvae infest ripening pods on the tree and persists in the stored fruits. The larvae feeds internally on the pulp and seeds and makes it unmarketable. Destroy the infected fruits and spray melthion @ 2ml per litre for 2-3 times at 10 days interval.

Mealy bug: It is a leading pest of tamarind in India, causing leaf-fall and sometimes shedding of young fruits. Foliar spray with chloropyriphos (0.02%) or imidacloprid (0.04%) or deltamethrin (0.15) or dichlorovos (0.05%) as prophylactic or on observing the infestation can control the pest

Diseases

Powdery mildew: A mildew is a common occurrence in nursery seedlings. The disease causes defoliation and early growth is severely retarded. Foliar sprays of wettable sulphur @ 3g/L at 15 day intervals is the most economical method of its control.

Cardamom (Small)

Botanical Name: *Elettaria cardamomum* Maton

Family: Zingiberaceae

Commercial Part: Fruit (Capsule)

Indian Names: Hindi: Chhotielaichi, Bengali: Chhotielachi, Gujarati: Elaychi, Kannada: Yelakki, Malayalam: Elathari, Marathi: Velchil, Oriya: Alaichi, Punjabi: Elaychi, Sanskrit: Ela, Tamil: Yelakkai or Elakkai, Telugu: Yealak-Kayulu or Elakkayi, Urdu: Ilaychi

Cardamom is one of the oldest spices that are used today. It has origin in the South Indian Western Ghats' evergreen forests. Commercially, dried fruits (capsules) are used as spice. Cardamom seeds contain essential oil which imparts its characteristic flavour. The major components of cardamom oil are 1,8 cineole, terpinyl acetate, linalyl acetate and linalool which are responsible for its flavour.

India and Guatemala are major producing countries. In India, Kerala, Karnataka and Tamil Nadu are the major producing states.

Uses

Cardamom is extensively used as a flavouring substance in whole as well as in powder form. It is used in baked goods and confectionaries. The major use is for

the preparation of 'gahwa' – a strong cardamom coffee concoction which is a symbol for hospitality among Arabs.

Types/cultivars

The cardamom cultivars are divided into Mysore, Malabar, and Vazhukka varieties based on the characteristics of the panicle, adaptability, shape, and size of the capsules. Mysore, a cultivar with upright panicles, is primarily grown in Kerala and some regions of Tamil Nadu. Malabar, a cultivar with prostrate panicles (panicles spreading on the ground), is mainly grown in Karnataka. The most popular variety in Kerala in recent years is Vazhukka, another cultivar with semi-erect panicles. It is thought to be a naturally occurring cross between Malabar and Mysore varieties.

Fig. 5.26: Malabar type

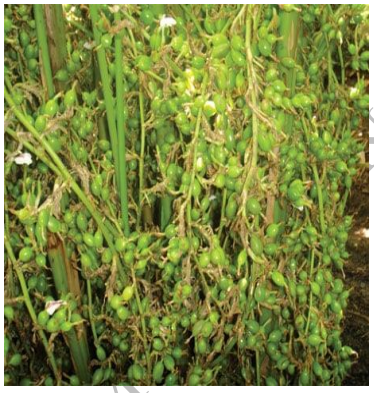


Fig. 5.27: Mysore type

Fig. 5.28: Vazhukka type

Some of the improved varieties of cardamom with high yield potential and superior capsule characters released from research organizations include, ICRI 1, ICRI 2, ICRI 3, IISR Avinash, IISR Vijeta. Among these IISR Vijeta is tolerant to Katte, a viral disease.

Apart from these, there are farmers' varieties like Njallani green gold and Vander cardamom which are also popular in cardamom growing regions.

Climate and Soil

Cardamom grows well in areas with well distributed annual rainfall, high humidity levels, and warm weather. The following are the climatic requirements for cardamom cultivation:

Altitude: 600-1200 m above mean sea level

Temperature: 15-35 ^{O}C

Rainfall: 1500-2500 mm

Relative Humidity: 75-90%

Cardamom thrives wells in forest soils rich in loam. These soils often have a pH between 5.5 and 6.5, making them acidic in nature. Cardamom plants thrive best in humus-rich soils with low to moderate amounts of available phosphorus and medium to high amounts of available potassium.

Propagation

Cardamom can be propagated by sexual and asexual means. Propagation by vegetative means through suckers produces true type and uniform plants but many times it may result in spread of viral disease, "katte". Seedling propagated plants may not be true to their parent but it is the cheaper method and avoids spread of viral disease. Production of planting materials through tissue culture is an alternative method of propagation.

Clonal nursery

When propagated vegetatively, a mature tiller or sucker, containing a portion of the rhizome and a developing shoot, represents a planting unit. Trenches of 45 cm wide, 45 cm deep, and of convenient length are made. They are then filled with top soil, sand, and good-quality compost to produce healthy planting material. Suckers are planted in these ditches with a 1.8 m x 0.6 m spacing. Building a pandal provides overhead shade therby protecting planted suckers from the sun and desiccation. Watering is done once in a fortnight for better establishment. Nutrients are supplied in 2-3 splits by applying fertilizers at 48:48:96 g NPK per sucker from the second month after planting. Application of neem cake @ 100-150 g/ plant is desirable. In ten months, about 15- 20 good quality planting units can be produced from a mother clump.

Fig. 5.29: Planting of suckers for clonal nursery

Seedling nursery

Cardamom is commercially propagated by seedlings which are raised two stage nurseries, i.e., the primary nursery and secondary nursery.

Primary nursery

A well-drained site, near a permanent source of water, is ideal for a cardamom nursery. The soil is dugged to a depth of 30 cm to bring it to fine tilth. Bed of 6 m length, 1 m width and 20 cm height are made and covered with a thin layer of fertile forest soil.

High yielding and disease-free mother clumps are identified for seed collection. Fully ripened capsules are collected during September only from second and third pickings (harvest). Each fruit may contain 15-20 seeds. Around 3000-5000 seedlings can be produced from one kilogram of ripe fruits (about 500-800 fruits). The seeds are extracted from fruits and washed repeatedly in water to get rid of the mucilage adhering to the seeds. The seeds are dried under shade after mixing with ash. Cardamom seeds are recalcitrant (desiccation intolerant) and viability of the seed is lost during storage on loss of moisture. Therefore, seeds should be sowed as soon as possible after extraction, ideally within 15 days. Cardamom seeds have thick seed coat and take long time to germinate and do not germinate uniformly. This problem can be overcome by acid treatment (scarification) with 25% nitric acid. For this, the extracted seeds immersed in 25% nitric acid for 10 minutes after placing them in loosely tied nylon net. The seeds are then removed from acid and washed repeatedly in water to remove acid traces. In Karnataka, September is the best time to sow, whereas in Kerala and Tamil Nadu, November to January is the best time.

The seeds are sown 1-2 cm apart within the row and the rows are spaced 10 cm apart from each other. For a bed measuring 6 m x 1 m, 30–50 g of seed will be needed. The beds are mulched with paddy straw after sowing. To ensure adequate moisture levels and to encourage germination, nursery beds are periodically watered. Beginning in roughly 20 to 25 days, germination could take up to two months to complete. Mulch is removed when seedlings emerge from the beds. The seedlings are regularly watered and protected by providing overhead shade. The seedlings are ready for transplanting to the secondary nursery at 3-4 leaf stage.

Secondary nursery

There seem to be two ways to raise seedlings in the secondary nursery.

Bed nursery: The beds are prepared as described in primary nursery. The bed is covered with a layer of compost that has been properly mixed with soil.

Seedlings of 3-4 leaves from the primary nursery are uprooted and transplanted in the secondary beds at a distance of 20 to 25 cm. Mulching and watering have to be done immediately after transplanting. Each bed is applied with 90:60:120 g NPK, in three equal splits. The interval between two applications is 45 days. After each fertilizer application, earthing up should to be done and once in 20-25 days, hand weeding needs to be taken up. To encourage better tillering, overhead shade is removed a month prior to uprooting the seedlings from the bed. The seedlings take around 8-10 months for attaining the field planting stage after planted in the secondary bed.

Activities

Activity 1: Demonstrate the processing of cinnamon.

Material required: Secateurs, brass or stainless knife, brass rod, cinnamon plant

Procedure:

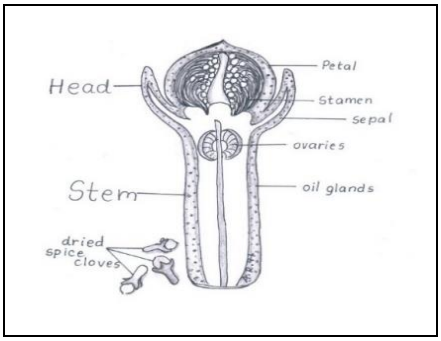
- Remove branches that are 1 to 2 cm thick and have turned brown.
- Use a knife to scrape off the delicate outer bark.
- Brass rod rubbing on the stripped stem will help to release the inner bark.
- Using a small, sharp knife, make 30 cm-distance incisions all the way around the stem.
- Cut the stem lengthwise with long incisions so that the bark may be gently peeled off the stem.
- Stack the removed bark pieces one on top of the other.
- Dry them in the shade after rolling them into a cylinder.

Activity 2: Identification of different parts of clove bud

Material required: Pen, pencil, notebook, clove bud

Procedure:

- Draw the diagram a clove bud and name the parts



Note down the length and girth of stem and head of clove buds

Activity 3: Visit a nutmeg plantation

Material required: Pen, pencil, notebook

Procedure:

Make the following observations during the visit

- Conditions under which it cultivated (As an intercrop under coconut/arecanut/ monocrop)
- Spacing adopted
- Approximate height of the tree
- Time of flowering and harvest
- Collect the samples of leaves/nut/mace

Check Your Progress

A. Fill in the Blanks

1. The economic part used in cinnamon is ……
2. The economic part used in clove is ……
3. The major constituent of clove oil is ……
4. The number of cloves required to make one kg ……
5. …… is the botanical family of nutmeg
6. The aril of seed in nutmeg is referred as ……
7. Allspice is structurally hermaphrodite, but, functionally ……
8. Commercial method of propagation of all spice is ……
9. The edible part in tamarind is ……

10. ..... is a major disease of tamarind seen at seedling stage

B. Multiple Choice Questions

1. Spacing recommended for cinnamon

   a) 2m x2 m

   b) 3m x 3m

   c) 5m x 5m

   d) 7m x 7m

2. The young cinnamon plants are cut close to the ground to a height of 15 cm from the stump to encourage side shoots. It is called

   a) Pruning

   b) Training

   c) Coppicing

   d) Desuckering

3. Clove plant originated in

   a) India
   b) Brazil
   c) Indonesia
   d) Srilanka

4. Following is a variety of nutmug

   a) Konkan swad
   b) Nityashree
   c) Navashree
   d) Konkan Tej

5. The ratio of nutmeg to mace yield is

   a) 1:1
   b) 3:1
   c) 4:1
   d) 10:1

6. For proper pollination the ratio of female to male plants in allspice plantation is

   a) 6:2

   b) 8:1

c) 9:2

d) 10:1

7. Duration required for allspice plants for planting to flowering

a) 2-4 years

b) 10-12 years

c) 8-10 years

d) 5-6 years

8. The sour taste of tamarind is due to presence of

a) Oxalic acid

b) Tartaric acid

c) Ascorbic acid

d) Malic acid

C. Match the Columns

A	B
1.Cassia bark	a) Finest quality bark
2. Cinnamon bark	b) Scrapped thick bark pieces
3. Quill	c) Delicate flavour
4. Chips	d) Hash flavour
5.Koker	e) Fruits
6. Mother of clove	f) Fungal disease
7. Sudden death	g) Defective cloves
8. Mace	h) Disease
9. Thread blight	i) Aril
10. Myristicin	j) Disease
11. Stem borer	k) Nutmeg Oil

12. Powdery mildew	l) Insect

D. Subjective Questions

1. Differentiate between cinnamon and cassia bark.
2. What do you mean by coppicing? What is the objective of this operation?
3. Briefly explain the propagation of cinnamon.
4. Mention the types cloves recognized in the international trade.
5. Briefly explain the harvesting and processing of clove.
6. Write a brief note on the soil and climatic requirement of nutmeg
7. What is significance of vegetative propagation in nutmeg?
8. Mention the major insect and disease affecting all spice
9. Explain the method of propagation of tamarind.
10. List three improved varieties of tamarind.

Session 2: Cultivate Pod Spices

Cardamom (Small)

Botanical Name: *Elettaria cardamomum* Maton

Family: Zingiberaceae

Commercial Part: Fruit (Capsule)

Indian Names: Hindi: Chhotielaichi, Bengali: Chhotielachi, Gujarati: Elaychi, Kannada: Yelakki, Malayalam: Elathari, Marathi: Velchil, Oriya: Alaichi, Punjabi: Elaychi, Sanskrit: Ela, Tamil: Yelakkai or Elakkai, Telugu: Yealak-Kayulu or Elakkayi, Urdu: Ilaychi

Cardamom is one of the oldest spices that are used today. It has origin in the South Indian Western Ghats' evergreen forests. Commercially, dried fruits (capsules) are used as spice. Cardamom seeds contain essential oil which imparts its characteristic flavour. The major components of cardamom oil are 1,8 cineole, terpinyl acetate, linalyl acetate and linalool which are responsible for its flavour.

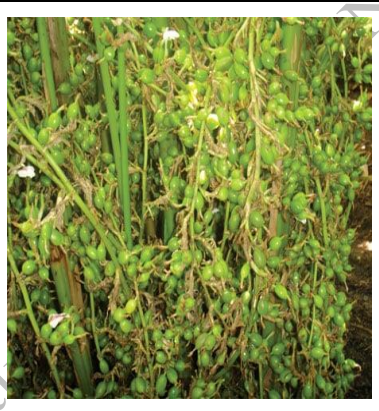
India and Guatemala are major producing countries. In India, Kerala, Karnataka and Tamil Nadu are the major producing states.

Uses

Cardamom is extensively used as a flavouring substance in whole as well as in powder form. It is used in baked goods and confectionaries. The major use is for the preparation of 'gahwa' – a strong cardamom coffee concoction which is a symbol for hospitality among Arabs.

Types/cultivars

The cardamom cultivars are divided into Mysore, Malabar, and Vazhukka varieties based on the characteristics of the panicle, adaptability, shape, and size of the capsules. Mysore, a cultivar with upright panicles, is primarily grown in Kerala and some regions of Tamil Nadu. Malabar, a cultivar with prostrate panicles (panicles spreading on the ground), is mainly grown in Karnataka. The most popular variety in Kerala in recent years is Vazhukka, another cultivar with semi-erect panicles.t is thought to be a naturally occurring cross between Malabar and Mysore varieties.

		
Fig. 5.26: Malabar type	*Fig.* 5.27: Mysore type	*Fig.* 5.28:Vazhukka type

Some of the improved varieties of cardamom with high yield potential and superior capsule characters released from research organizations include, ICRI 1, ICRI 2, ICRI 3, IISR Avinash, IISR Vijeta. Among these IISR Vijeta is tolerant to Katte, a viral disease.

Apart from these, there are farmers' varieties like Njallani green gold and Vander cardamom which are also popular in cardamom growing regions.

Climate and Soil

Cardamom grows well in areas with well distributed annual rainfall, high humidity levels, and warm weather. The following are the climatic requirements for cardamom cultivation:

Altitude: 600-1200 m above mean sea level

Temperature: 15-35 ^{O}C

Rainfall: 1500-2500 mm

Relative Humidity: 75-90%

Cardamom thrives wells in forest soils rich in loam. These soils often have a pH between 5.5 and 6.5, making them acidic in nature. Cardamom plants thrive best in humus-rich soils with low to moderate amounts of available phosphorus and medium to high amounts of available potassium.

Propagation

Cardamom can be propagated by sexual and asexual means. Propagation by vegetative means through suckers produces true type and uniform plants but many times it may result in spread of viral disease, "katte". Seedling propagated plants may not be true to their parent but it is the cheaper method and avoids spread of viral disease. Production of planting materials through tissue culture is an alternative method of propagation.

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When propagated vegetatively, a mature tiller or sucker, containing a portion of the rhizome and a developing shoot, represents a planting unit. Trenches of 45 cm wide, 45 cm deep, and of convenient length are made. They are then filled with top soil, sand, and good-quality compost to produce healthy planting material. Suckers are planted in these ditches with a 1.8 m x 0.6 m spacing. Building a pandal provides overhead shade therby protecting planted suckers from the sun and desiccation. Watering is done once in a fortnight for better establishment. Nutrients are supplied in 2-3 splits by applying fertilizers at 48:48:96 g NPK per sucker from the second month after planting. Application of neem cake @ 100-150 g/ plant is desirable. In ten months, about 15- 20 good quality planting units can be produced from a mother clump.

Fig. 5.29: Planting of suckers for clonal nursery

Seedling nursery

Cardamom is commercially propagated by seedlings which are raised two stage nurseries, i.e., the primary nursery and secondary nursery.

Primary nursery

A well-drained site, near a permanent source of water, is ideal for a cardamom nursery. The soil is dugged to a depth of 30 cm to bring it to fine tilth. Bed of 6 m length, 1 m width and 20 cm height are made and covered with a thin layer of fertile forest soil.

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Secondary nursery

There seem to be two ways to raise seedlings in the secondary nursery.

Bed nursery: The beds are prepared as described in primary nursery. The bed is covered with a layer of compost that has been properly mixed with soil.

Seedlings of 3-4 leaves from the primary nursery are uprooted and transplanted in the secondary beds at a distance of 20 to 25 cm. Mulching and watering have to be done immediately after transplanting. Each bed is applied with 90:60:120 g NPK, in three equal splits. The interval between two applications is 45 days. After each fertilizer application, earthing up should to be done and once in 20-25 days, hand weeding needs to be taken up. To encourage better tillering, overhead shade is removed a month prior to uprooting the seedlings from the bed. The seedlings take around 8-10 months for attaining the field planting stage after planted in the secondary bed.

Fig. 5.30: Seedlings in secondary nursery bed

Polybag nursery: This method uses polythene bags with a 100 gauge thickness and a 20 cm x 20 cm size. They are filled with potting mixture comprising of soil, FYM and sand (3:1:1 ratio). Seedlings from primary nursery are transplanted into bag. Seedlings, raised in the polybags, will be ready earlier for field planting as compared with bed nursery.

Fig. 5.31: Poly bag nursery

Planting and Cultural Practices

Planting: In Karnataka, 10-month-old cardamom seedlings are favoured for planting in the main field. While in Kerala and Tamil Nadu, 18 month-old seedlings are frequently utilised.

Land preparation: Since majority of cardamom plantation are on hill slopes, the land is prepared by contour terracing before planting. To shield the seedlings from direct sunshine, fast-growing shade trees such Dadap, Albizia, Karuna, Acrocarpus, Syzygium, Jack tree, etc. are planted. Before the start of the monsoon season, smaller pits of 45 cm^3 are prepared for planting Malabar varieties while larger pits of 90 cm * 90 cm * 45 cm are prepared for Mysore and Vazhukka varieties (April-May). 1/3rd of the pit is filled with the topsoil. Applying 100 g of rock phosphate along with the topsoil and 100 g of well-decomposed farmyard manure helps to ensure proper establishment and rapid growth of suckers. To prevent wind damage, suckers are given stakes, and the plant base is mulched with suitable material. For Mysore and Vazhukka cultivars, the suggested spacing is 3 m * 3 m and 2.4 m * 2.4 m respectively. For Malabar varieties, the ideal spacing is 1.8 m * 1.8 m or 2.0 m * 2.0 m.

Shade regulation

Summertime is an ideal time to do shade regulation, terracing, and pit opening in areas that are meant for new planting. In already-existing plantations, shade regulation is done in March and April. Shade trees branches are trimmed to let in around 40 and 60 percent of filtered light. To maintain a balanced canopy, shade trees have their branches pruned on all sides.

Fig. 5.32: Properly shade regulated plantation

Irrigation

Cardamom plantation requires irrigation during January to May at an interval of 10-15 days. Irrigation can be done either by hose or by micro-sprinkler or by drip method. On gentle sloppy areas, as a measure of soil and water conservation, small rectangle pits (silt pits) can be opened. When soil around the plant becomes compact and hard, it can be made loose by forking to a depth of 9-12 cm. This will promote root penetration.

Weeding

Cardamom is a surface feeder. Removal of weeds at frequent intervals is necessary during the first year of planting. In succeeding years, it is advised to perform 2-3 rounds of hand weeding at the base of the plants in May, September, and January, as well as slash weeding (cutting weeds with a specific slashing tool) in the interspaces.

Mulching

The cardamom plant base is covered with mulch of about 5-10 cm thickness with fallen leaves of the shade trees.

Cardamom is a cross pollinated crop and the major pollinating agent in is honey bee. In order to improve fruit set during the flowering season, it is preferable to keep three to four bee colonies per hectare. At the start of monsoon, mulch is taken from the base of the clumps to promote honey bee activity (May-June). Removal of dried leaves and yielded tiller is called trashing. Every year, it is undertaken when the monsoon season begins. Trashing can be done two to three times in high-density plantations when irrigation facilities are available.

Manuring

Following is Fertilizers Recommendation for Cardamom:

Soil application	Soil and foliar application
Rainfed - 75:75:150 NPK (kg/ha), two splits	37.5:37.5:75 NPK kg/ha and foliar spray of Urea (2.5%). Single super phosphate (0.75%) Muriate of potash (1.0%)
Irrigated – 125:125:250 NPK (kg/ha), three splits	

During the first year of planting, 1/3rd of the recommended dose of fertilizers is applied. It is increased to half in the second year and the complete dose of fertilizers starting in the third year. Mulch is removed from the plant basin and the panicles are trimmed prior to fertilizer application. A circular band of fertilizer

with a 15 cm width is applied around 30 cm distance from the cardamom clump. Once the fertilizer has been applied, the basin is mulched once again. During pre-monsoon application, organic manures, in the form of farmyard manure (5 kg/plant), are used.

Due to continuous rainfall and application of acid forming fertilizers, the soil generally becomes acidic. When the pH of the soil goes below 5.0, agricultural lime is applied @ 1 kg/plant/year in two splits during May and September. It is advised to apply a micronutrient blend made specifically for cardamom by ICAR-IISR twice to the leaves (5 g/L) (during May – June and September-October). This will enhance the yield.

Fig. 5.33: Cardamom plantation with bearing panicles

Harvesting and Processing

Sucker propagated cardamom plants start bearing in two years after planting whereas seedlings bear after three years. The capsules mature in 120-135 days after fruit set. Harvesting period in Kerala and Tamil Nadu is from June-July to January-February. In Karnataka, harvesting starts in August and extends up to December-January. Capsule do not mature at a time and hence they are harvested at an interval of 15 -30 days. The capsules are harvested at their physiological maturity instead of complete ripening stage. The correct stage of harvest is when the skin of the fruit is green but seeds inside turn black. In addition to splitting capsules during processing, harvesting ripe capsules results in the loss of green colour. As the cardamom capsules are close to the ground, they need to be washed with clean water to remove the dirt adhering to them. Immediate processing of capsules will retain the green colour.

Fig. 5.34: Harvesting of capsules

Fig. 5.35: Manual washing of capsules

The primary objective of drying (also called curing) of cardamom is to reduce the moisture of freshly harvested capsules from 80% to 10-12% through indirect heating. Two methods are employed to dry cardamom:

1. Natural or sun drying
2. Flue curing

Natural or Sun Drying

The harvested capsules are dried in the sun for five to six days. The duration of drying depends on the availability and duration of sunlight. Green colour of capsules is not retained in natural drying. Moreover, it causes the capsules to split. The export of these capsules is not common. In some areas of Karnataka, where there are no facilities for flue curing and there is a smaller harvest, sun drying is practiced.

Flue Curing

This method of drying produces high quality green cardamom. It works on the principle of convective heat transfer. A typical curing house has a furnace (for burning the wood), flue pipes made of galvanised iron, and racks for stacking the trays

For the drying of 1 kg of fresh cardamom capsules, 3–4 kg of firewood is needed. In the drying chamber, the washed capsules are evenly distributed in a single layer on the trays and placed on the racks. The drying room is then sealed. Hot

air was produced by burning firewood in the furnace. The flue pipes, which are positioned a few centimetres above the floor, allow this hot air to travel through them. The chamber's temperature ranges from 45 to 55 °C. When the capsules release the moisture, this temperature is held for 3–4 hours. Opening the ventilators and turning on the exhaust fans removes the moisture or water vapour produced during this step. The ventilators are shut after the moisture has been removed. After then, the chamber's temperature is held at 45–55°C for roughly 18–24 hours. The temperature is increased to 60-65°C for the last one to two hours of drying.

Cardamom dryers that are more efficient and highly automated have been developed in recent years and are being utilised widely using alternative fuel sources such as kerosene, liquid petroleum gas (LPG), and diesel or with a combination of fuels. Such enhanced technologies preserve colour and result in faster drying times (16-18 hours).

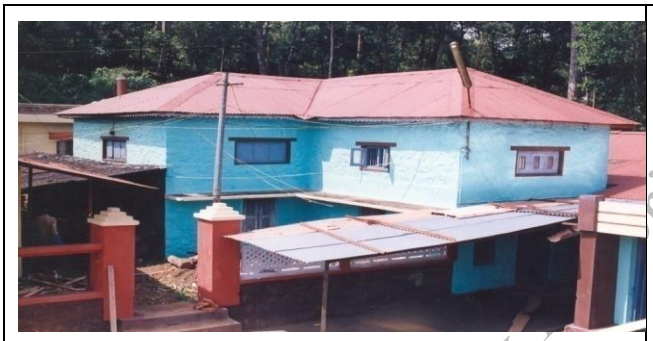


Fig. 5.36: Conventional cardamom curing chamber

Fig. 5.37: Modern cardamom curing chamber

The dried capsules have dried floral parts attached to them. Polishing is done remove the dried floral parts. Polishing can be done manually or by using machines. The capsules are graded colour, size and weight per volume. Important grades of cardamom include Alleppey Green Extra Bold (AGB), Alleppey Green Superior Coorg Green Extra Bold (CGEB), Coorg Green Bold (CGB) and Bleached (BL). Gunny bags lined with 300 gauge black polythene is for storing cured cardamom capsules.

Fig. 5.38: Cardamom packing

Pests and Diseases

Insects-Pests

Cardamom thrips (*Sciothrips cardamomi*): Nature of damage of this insect is in the form of laceration and feeding on leaves, shoots, inflorescences and capsules by larvae and adults. When the panicles are infested, flowers and immature capsules shed. A corky look caused by infestation on immature capsules lowers their market value. During the months of March, April, May, August, and September, spray pesticides such quinalphos (0.025%).

Fig. 5.39: Thrips damage

Fig. 5.40: Panicle borer damage

Shoot and capsule borer (*Conogethes punctiferalis*): The larvae eat the insides of the pseudostems by drilling holes in them. When panicles dry out outside of the damaged area, the "dead heart" symptom develops. Additionally, the larvae eat the seeds and harm the capsules. During September and October, infected suckers should be destroyed. Quinalphos (0.075%) should be sprayed twice: in February–March and in September–October, respectively, when panicles and fresh shoot emergence are visible.

Diseases

Azhukal or capsule rot (*Phytophthora nicotianae var. nicotianae*and *P. meadii*): The disease incidence starts with the beginning of South-West monsoon. Water soaked lesions appear on young leaves and capsules. Later, such capsules produce a foul smell and drop off. Infected mature capsules become shrivelled on drying. Prophylactic sprays with Bordeaux mixture (1%) during May-June and further sprays repeated during July-August will help to

manage the disease. Application of biocontrol agents like *Trichoderma viride* or *T. harzianum*@ 1 kg during May and September-October can manage the disease effectively.

Fig. 5.41: Azhukal disease on panicle

Fig. 5.42: Katte disease symptom on leaves

Rhizome rot or clump rot (*Pythium vexans, Rhizoctonia solani* and *Fusarium* spp.): Yellowing and drooping of the leaves, as well as brittle collars, are signs of the disease. The rhizomes and roots later begin to decay. In the months of May and June, soak the plant basins in copper oxychloride 0.25% and spray the plants with 1% Bordeaux mixture.

Mosaic or Katte disease: The topmost leaf displays the early sign as thin chlorotic specks. On the leaf blade, the recognisable mosaic symptoms are visible. The cardamom mosaic virus is what causes the disease (CdMV). The aphid are the vectors for virus transmission and it is also transmitted through infected rhizomes. In katte-prone locations, use the plant resistant IISR Vijetha cultivar. At a dosage of 0.1%, neem-based pesticides can reduce the number of aphids.

Large Cardamom

Botanical Name: *Amomum subulatum* Roxb

Family: Zingiberaceae

Commercial Part: Fruit (Capsule)

Indian Names: Hindi: Bara Elaichi Bengali: Bara Elaichi Malayalam: Perelam Punjabi: Bara Elaichi Sanskrit: Brihadaela Tamil: Periyayalam Telugu: Peddayelaki Urdu: Bara Elaichi

Large cardamom is an important spice crop of sub-Himalayan region of India covering state of Sikkim and Darjeeling district of West Bengal. It is also cultivated in other North Eastern states like Arunachal Pradesh, Nagaland, Mizoram, Manipur, Meghalaya and Assam. Sikkim ranks first in the area and production of large cardamom. Besides, it is also cultivated in our neighbouring countries like Nepal and Bhutan.

Fig. 5.43: Large cardamom capsules

Climate and Soil

It is a sciophyte that thrives in the partial shade and is grown in tracts with evenly distributed rainfall spread out over 200 days for a total of roughly 3000-3500 mm/year. Ideal soil for large cardamom forest loamy soils with gentle to medium slope. Waterlogged condition is harmful to plants. It requires partial shade (50%).

Uses

Large cardamom is mostly used as a spice for culinary purpose and in several Ayurvedic preparations. Capsules contains 2-3% essential oils. It has diuretic and cardiac stimulant properties.

Varieties

Six popular cultivars of large cardamom are recognized in Sikkim viz., Ramsey, Ramla, Sawney, Varlangey, Seremna, Dzongu and Golsey. ICRI Sikkim 1 and

ICRI Sikkim 2 are two high yielding varieties released from Indian Cardamom Research Institute, Regional Station, Gangtok.

Propagation

Like small cardamom, large cardamom can also be propagated by seeds and suckers. The procedures for both these methods of propagation in large cardamom are similar to small cardamom explained in the previously.

Land preparation

The area chosen for planting is made completely clear of all overgrowth, weeds, etc. Old and aged cardamom plants if any, can be removed as well. Before the start of pre-monsoon showers, pits of 30 cm * 30 cm * 30 cm size are prepared on contours at 1.5 m * 1.5 m spacing. Topsoil is mixed with farmyard manure (FYM,) at the rate of 1-2 kg per pit, while filling the pits

Planting

When there is sufficient soil moisture viz., between June and July, planting is taken up. For planting, a mature tiller or a seedling with two to three tillers is used. Avoid planting deeply in the ground. Mulching is done at the plant base and staking is required to prevent lodging from strong winds and rain.

Mulching

Mulching with easily degradable organic materials at the base of the plants is beneficial for preserving soil and moisture. Mulch enhances the fertility and health of the soil. Mulching materials include dried organic matter, leaves, weeds and other things.

Manures/ Fertilizers

It is advantageous to apply 2 kg of well-decomposed farm yard manure per plant in April and May. Application of inorganic fertilizers may not be required if all crop residues are recycled in the plantation and FYM is used regularly. However, in high-productivity plantations, fertilizers @ 20: 30: 40 kg N, P, and K per hectare may be applied in two splits, with the entire P in April and half N and K during April and September.

Watering

Large cardamom plants can't survive well when there's a moisture shortage. Watering is necessary during the first year after planting, at least once every ten days from September to March. Then, during the summer, irrigation is to be provided.

Shade management

Crop development and productivity are hampered by either heavy or light shading. It is found that 50% shade is best. It's crucial to prune the branches of shade trees before the monsoon season begins in June or July. However, excessive exposure to direct sunlight also causes burning of the leaves. Therefore, for healthy growth, early flowering, and a higher yield, careful shade management is crucial.

Weed control

For the first two to three years, three rounds of weeding are required to effectively check the weed growth. Weeds are manually removed either by hands (from the area surrounding the plant base) or by a sickle (in the open areas). Dried plant parts and other plant residues are utilized as mulch around the plant.

Fig. 5.44: Large cardamom plantation

Harvesting

When the seeds of the topmost capsules in the spike start to turn brown, it is time to harvest large cardamom. The tillers are cut at a height of 30 to 40 cm above the ground and allowed to fully mature for 10 to 15 days. Using specialized "Elaichi chhuri" blades, the spikes are extracted. Freshly harvested capsules contain 80% to 85% moisture. It needs to be dried right away. Bricks and dirt are used to build the traditional kiln known as *bhatti*. The fresh cardamom is evenly spread on drying platforms. The capsules are exposed to hot firewood smoke. The entire drying process takes 35–40 hours.

Flue pipe curing system: This is comparable to the process used in small cardamom. After the chamber is kept at 40°C, the capsules are arranged in one or two layers over the wire mesh floor and shelves. The curing room is immediately sealed after the capsules have been spread and hot air is then

circulated through the furnace into the flue pipes to raise the temperature to around 45–50°C where it will remain for roughly 3–4 hours. At this point, the capsules start to sweat, which lets the moisture out. Then the ventilators are opened to completely remove the accumulated moisture from the chamber. Additionally, the ventilators are shut off, and the temperature is kept between 40 and 45 °C. The capsules are stirred one or two times to achieve consistent drying. The entire curing procedure lasts between 28 and 29 hours. The following are the benefits of using this approach as opposed to the Bhatti system:

(i) The pink colour and sweet camphor aroma of the original product are still intacted.

(ii) Securing a higher market price.

(iii) Firewood usage is lower and curing costs are relatively cheap.

(iv) The entire curing procedure is finished in 28 to 29 hours.

The capsules that have been properly cured are then immediately gathered and either rubbed in trays or put through a cardamom polishing process to remove the dry floral part. Produce is first cleaned before being put in polythene-lined gunny bags and kept in wooden crates. On average, the recovery of cured cardamom is 25% of fresh cardamom.

Yield: 400-500 kg dried capsules/hectare

Pests and Diseases

Insects-Pests

Leaf-eating caterpillars (*Artonachorista*), banana aphids (*Pentalonia nigronervosa*), and shoot flies (*Merochlorops dimorphus*) are insects that attack large cardamom. Pest control measures include phytosanitation, and removal and burning of infested tillers.

Diseases

Chirkey disease: The first sign of the disease is the emergence of mosaic-like patches on the young leaves with pale streaks that eventually turn brown and cause the plants to wither away. The crop's development and yield will be impacted. Aphids are the vectors that spread the virus. Planting infected suckers is another way that it spreads.

Foorkey disease: In the affected plants, a large number of tiny tillers with stunted growth appear at the base of the plant and fail to produce fruitful inflorescence, spikes, or yield.

The affected plants cannot be controlled using chemicals because both of the aforementioned diseases are viral. However, disease-free planting material should be utilised, and infected plants should be removed and burned.

Blight (*Colletotrichum gloeosporioids*): Water-soaked lesions on the leaves quickly grow, consolidate, and cover the entire leaf lamina, giving the plant a blighted appearance. Collateral hosts including ornamental basil, wild colocasia, canna, marigold, and *Amomum dealbatum* need to be destroyed. Apply 2kg/clump of fortified Trichoderma with FYM (1:100) to the plant basin. To lessen the likelihood of disease, it is advised to pre-treat suckers with the bioagent *Pseudomoas fluorescence* at a concentration of 5 litres per 100 litres of water at the time of planting.

Activities

Visit small cardamom plantations and study the cultivation practices

Material required: Pen, pencil and notebook etc.

Procedure:

Make the following observation during visit

- Conditions under which it cultivated
- Name of varieties
- Spacing adopted
- Approximate height of the tree
- Time of flowering, fruiting and harvesting

Check Your Progress

A. Fill in the Blanks

1. Mysore varieties cardamom have ..... type of panicles.
2. The leading state in small cardamom production is .....
3. Single capsule of small cardamom contains ..... seeds.
4. .....is a virus tolerant variety of cardamom.
5. Large cardamom requires .....per cent shade for its growth.
6. Large cardamom is a shade loving plant, hence referred as .....
7. Dried capsule yield of large cardamom per hectare is .....

B. Multiple Choice Questions

1. Cardamom is propagated commercially by
   a) Suckers
   b) Seeds
   c) Tissue culture
   d) Rhizomes
2. One kg of fresh cardamom can produce
   a) 100-200 seedlings
   b) 500-1000 seedlings
   c) 3000-5000 seedlings
   d) 200-300 seedlings
3. Which of the following is a serious viral disease in cardamom
   a) Cardamom
   b) Rhizome rot
   c) Katte
   d) Necrosis
4. Large cardamom is also known as
   a) Nepal Cardamom
   b) Bhutan cardamom
   c) Indian Cardamom
   d) Bengal Cardamom
5. Colour of the capsules of large cardamom is
   a) Greenish yellow
   b) Reddish- brown
   c) Greenish white
   d) Yellowish green
6. Large cardamom belongs to ------ genus
   a) Elettaria
   b) Aframomum
   c) Ammomum

d) Zingiber

7. The major producing state of large cardamom in India

a) West Bengal

b) Kerala

c) Assam

d) Sikkim

C. Match the Columns

A	B
1. Mysore	A. Removal of dry leaves 3.
2. Malabar	B. Prostrate panicle 2.
3. Trashing	C. Erect panicle 1.
4. Suckers	D. Viral disease spread 4.
5. Ramsey	E. High yielding variety 6.
6. ICRI Sikkim-1	F. Viral disease 7.
7. Chirke	G. Traditional method of curing 8.
8. Bhatti	H. Local cultivar of large cardamom 5.

D. Subjective Questions

1. Explain the clonal nursery in cardamom
2. Explain the curing process in cardamom
3. What is the recommended dose of fertilize for cardamom? Explain time of application, number of splits and placement of fertilizers.
4. Write the advantages of the flue curing method of processing of large cardamom
5. Name two local and improved varieties of large cardamom.
6. Write about the climatic requirement of large cardamom.

Session 3: Cultivate Black Pepper

Black Pepper

Botanical Name: *Piper nigrum* L.

Family: Piperaceae

Commercial Part: Fruit

Indian Names: Kannada: Kare menasu, Bengali: Kala morich, Gujarati: Kalamari, Oriya: Gol maricha, Marathi: Mira, Malayalam: Kurumulaku, Kashmiri: Marutis, and Hindi: Kali mirch Sanskrit: Marich ushna; Tamil: Milagu; Telugu: Miriyala tige; Urdu: Kali mirch; Punjabi: Kali mirch

Black pepper is one of the leading spices of the world which has its origin in India. It was also one of the spices that had lured the European traders to search for a sea route to India. Due its importance and extensive use black pepper is regarded as "King of spices" or "black gold". Dried berries or fruits are the economical parts in black pepper which are obtained from a perennial woody climber. It is used as both as spice and medicine. The dried berries contain piperine (compound imparting pungency) and sesquiterpenoids and monoterpenoids (components of essential oil imparting flavor). Western Ghats of south India is the natural habitat of this plant. Major producing countries of black pepper are Vietnam, Brazil, Indonesia, India, Sri Lanka and China. India, once a largest producer and exporter of black pepper has lost its position to Vietnam in recent years. It is mainly grown in the south Indian states of Karnataka Kerala and Tamil Nadu.

Uses

An indispensable ingredient in culinary preparations, pepper is also utilized in spice blends. In products like white sauces and potato meals, where black particles of black pepper are not preferred, white pepper (pepper corn without outer skin) is utilised. The other products of this spice are pepper oleoresin, pepper oil, micro encapsulated pepper, frozen pepper, green pepper in brine, and dried green pepper. Ayurveda and Sidda, two Indian medical systems, use black pepper extensively. Piperine, the pungent component of pepper oleoresin, is employed by the pharmaceutical industry to increase bioavailability.

Fig. 5.45: Different types of Peppers (Fresh green, Dehydrated green, Black and white peppers)

Climate and soil

Being a crop of humid tropics, black pepper performs well in hot humid climate of Western Ghats of south India. It requires support and shade for its growth.

Following are the climatic conditions required cultivation of black pepper:

Altitude: Up to 1500 m above mean MSL (Mean sea level)

Mean temperature: 23-32 ^{O}C

Rainfall: 1250- 2000 mm

Relative Humidity: 75-80%

Black pepper grows well in a variety of soil types. Ideal pH is 5.5 to 6.5. It is grown under different situations in India such as homestead gardens in the west coast with coconut or areca nut, sole crop in the midlands, higher elevations as a mixed crop in coffee, tea and coffee plantations.

Varieties

India is home to more than 75 different black pepper cultivars. In Kerala, Karimunda is the cultivar that is most often grown. Narayakodi and Kottanadan in Kerala and Malligesara and Uddagare in Karnataka are other prominent cultivars. Several varieties of black pepper have been released for cultivation by research institutes. Panniyur-1, a hybrid is the most popular among them.

Fig. 5.46: Panniyur -1 vine

Propagation

Black pepper vine produces three types of shoots viz., orthotropes or vertical shoots, plagiotropes or horizontal shoots and runners. Among them, runners are commonly used for propagation, though terminal shoots can also be used. Seed propagation is not employed in black pepper as seedlings will not be genetically uniform.

In order to produce large number of plants, rapid multiplication techniques have been developed. They include

- Split bamboo method
- Serpentine method

Split bamboo method: This approach involves opening a trench that is 45 cm deep, 30 cm wide, and have appropriate length. As a rooting medium, a 1:1:1 mixture of top soil, sand, and FYM (farm yard manure) is poured into the trench. A 1.25 m long bamboo stem that has been cut in half is positioned on one side of the trench at a 45° angle on a sturdy horizontal support. PVC pipe split halves are an additional option. The split end of the PVC or bamboo pipes must be facing up. Rooted cuttings are planted in trench at the rate of one cutting for each bamboo split. Rooting media is placed in the bamboo splits close to the base. The developing vine, which is attached to bamboo split, emerges from the cutting. It is important to make sure that the nodes are firmly placed against the rooting medium. Cuttings can be separated after around three months. The roots of the vine are left intact as it is cut into single nodded cuttings. They are planted in plastic bags. Trichoderma @ 1g and VAM @ 100 cc/kg of soil can be added

when the potting mixture is being filled into the bags. This method of black pepper propagation has a number of advantages over the conventional method which are:

- Improved field establishment,
- Faster rate of multiplication (1:40),
- Strong roots
- More rapid field expansion

Fig. 5.47: Split bamboo nursery

Fig. 5.48: Serpentine method

Fig. 5.49: Black pepper cuttings

Serpentine method: In this method, cuttings raised in larger polybags filled with potting mixture are allowed grow horizontally along the ground in a protected area such a shade house or poly house. As pepper vine grows horizontally, a smaller bag of 20 x 10 cm filled with potting mixture are placed under each node. It must be ensured that the nodes are in contact with the medium. This can be accomplished by inserting a bent twig or the midrib of a coconut leaflet at each node. In about three months, first 10-12 nodes would produce profuse roots which can be separated along with the bag. New sprout can be seen in the cutting in about a week. We can get around 60 cuttings from each mother plant.

Establishment of pepper plantations

Black pepper plants are sensitive to direct exposure to sunlight. To avoid sun scorching during summer, black pepper is preferably planted on the lower half of northern and north eastern slopes.

Planting standards

Being a climber, black pepper requires a support. These supports are called standards which could be a living or non-living. Pits of 50 cm^3 are dug at a spacing of 3 m × 3 m and re-filled with top soil and FYM. During May, with the onset of pre-monsoon showers, stem cuttings of standard trees are planted in the pits. Commonly used standard trees are Erythrina, Garuga, silver oak or Alianthus.

Planting of black pepper cuttings

With the onset of monsoon, pits of 50 cm^3 are opened 30 cm away from the base of the standards. These pits are filled with a mixture of top soil, FYM @ 5 kg and rock phosphate @ 150 g per pit. To avoid soil borne pathogens and nematodes, applying neem cake @ 1 kg and *Trichoderma harzianum* @ 50 g per pit at the time of planting will be desirable. Two to three rooted cuttings of black pepper are planted in the pits.

Cultural practices

Vertical shoots of pepper vine produce clinging roots at the nodes which help them anchored to the standards. However, as the plants grow, shoots need to be tied to the standard regularly for better support.

In order to make the pepper vines to grow straight and to provide optimum light, regulation of shade is necessary by cutting or lopping the branches of standards trees. Excess shade during flowering and fruiting stage encourages disease or pest infestations. This operation should be done carefully from the fourth year onwards. Two lopping may be done once during June and the other during September.

Mulching with green leaf or organic matter is desirable which can be applied towards the end of north east monsoon. To avoid root damage, soil near the base of the vines should not be disturbed.

Manuring and Fertilizer Application

Recommended dosage of manures and fertilizers is FYM/Compost @ 10 kg/vine, Neem cake @ 1kg/vine and NPK @ 100:40:140 g / vine per year for black pepper vines (3 years and above). During the first year, 1/3rd of the recommended dose is applied and 2/3rd during the second year. From the third year onwards, entire recommended dose is given. The fertilizers are applied in two splits, the first during May-June and the second during August-September when sufficient soil moisture is available. The fertilizers are applied about 30 cm away from the vine in a circle and mixed in the soil. Foliar application of micronutrient mixture

specific to black pepper developed by Indian Institute of Spices Research, Calicut (Black pepper special) is recommended (dosage @ 5 g/L) twice, once during flowering and 30 days after the first spray for increasing the yield. If the soil is highly acidic, application of 500 g lime or dolomite per vine during April-May is recommended to correct the pH of the soil. This application may be taken up during alternate years.

Fig. 5.50: Black pepper vines on areca nut trees

Bush pepper

Normally, black pepper is propagated by runners or top shoots. However, the lateral or plagiotropic branches can also be used for multiplication with external application of auxin (indole butyric acid). Rooted lateral branches produce bushy plants instead of a vertically growing vine. Such plants are referred as bush pepper. Bush pepper can be cultivated as potted plants or even field grown bushes under shade. Advantage of bush pepper is that it yields green pepper throughout the year. Bush pepper can yield be up to 1 kg per bush after 3 years of planting.

Fig. 5.51: Bush pepper plants

Harvest and post-harvest management

Black pepper vines start yielding after three years of planting. The berries mature in 7-8 months. In India, peak season of harvesting of pepper is January-April in the hills of Western Ghats and December-January in plains. Stage of harvesting of pepper depends on the type of processed product.

Maturity stages for processing into different pepper products is shown in the table below:

S. No.	Stage	Product	
1	4-5 months after fruit set	Canned pepper	
2	10-15 days before maturity	Dehydrated green pepper	
3	Fully mature and when 1-2 berries start turning from yellow to red in each spike	Black pepper	
4	Fully ripe	White pepper	

The spikes are picked by hand and collected in bags or baskets. Traditionally, single pole bamboo ladders is used for climbing the standards for harvesting. We can obtain an average dry yield of 1000 to 1500 kg /ha.

Fig. 5.52: Pepper spikes ready for harvest

Processing black pepper

Processing of black pepper involves despiking, blanching, drying, cleaning, grading and packaging. Despiking is carried out with mechanical threshers to provide clean product.

Blanching: It is the process wherein the mature berries are dipped in boiling water for one minute before drying. To facilitate this, a perforated vessel can be used. This improves the quality of the black pepper in terms of uniform colour, reduced the microbial load, reduced drying time from 5-6 days to 3-4 days and removal of the extraneous impurities like dust.

Drying: Harvested pepper berries have moisture content of 65% to 70%. This needs to be reduced to safer levels of less than 10%. Traditionally, black pepper is dried by exposure to the sun. The despiked berries are spread on a concrete floor or tarpaulin. Duration of drying is around 3-5 days. The dry recovery of black pepper is around 30-35% depending on the cultivars.

Cleaning and Grading: The dried black pepper is cleaned to separate extraneous matter like pieces of spikes, pinheads (undeveloped berries), stones, soil particles etc. mixed with it. Grading of black pepper is done by using sieves into different grades based on size. The major grades of black pepper are Tellicherry Garbled Special Extra Bold (TGSEB) (4.8 mm), Tellicherry Garbled Extra Bold (TGEB) (4.2 mm), Tellicherry Garbled (TG) (4.0 mm), Malabar Garbled (MG) and Malabar Ungarbled (MUG).

Fig. 5.53: Dried black pepper

Processing white Pepper

White pepper is obtained by removing the pericarp (outer skin) of ripe pepper berries. It is generally prepared by retting (soaking) fully ripened berries in running water (or with frequently changing of water) for 7-8 days. This results in breakdown of the skin by microbial action. Then, the outer skin is removed, washed and dried so to reduce the moisture content to 12%. The recovery of white pepper is around 28 – 30%

Green pepper

Canned Green Pepper*:* The green pepper berries are despiked and washed. These are filled in to containers, such as bottles or cans, containing a diluted solution of sodium chloride or common salt. The cans are then sterilized after sealing using steam under pressure.

Dehydrated green pepper*:* Dehydrated green pepper is prepared from immature green pepper berries. The process involves blanching in boiling water for few minutes and drying in a cabinet dryer at 50°C. Upon rehydration, it gives a similar flavour, pungency and taste of canned green pepper. Advantage of this product is that it can be easily handled, stored and transported.

Packaging and storage

Black pepper berries are hygroscopic in nature and tend to absorb moisture which in turn lead to mould and insect attack. Pepper is packaged in bulk using woven polypropylene bags, multilayer paper bags, or jute bags with food-grade liners.

Pests and Diseases

Insects-Pests

Pollu beetle (*Lanka ramakrishnai*): Tender leaves and spikes are fed by the adult beetles. The grubs eat the interior tissues of fruits by boring into them. Spikes and berries, that have been infested, become black and rot. When crushed, the damaged berries crumble.

Control

Spray Quinalphos (0.05%) twice between June and July and September and October, or Quinalphos (0.05%) in July and Neemgold (0.6%) (An insecticide based on neem) in August, September, and October.

Top shoot borer (*Cydia hemidoxa*): The damaged shoots turn dark and begin to decay as a result of the larval feeding on internal tissues of tender terminal shoots.

Control

Spray quinalphos (0.05%) on tender terminal shoots. Spraying to be repeated at monthly intervals (during July-October).

Leaf gall thrips (Liothrips karnyi): The feeding of thrips on leaves results in upward curling of leaf margins which results in formation of leaf galls on the margins. Later, the leaves become malformed.

Control

Spray dimethoate (0.05%) during emergence of new growth.

Diseases

Phytophthora foot rot / quick wilt (*Phytopthora capsici*): The stem near the ground level gets infected and the rotting and death of vine occurs within 2-3 weeks. The affected portion emits bad odour. The necrosis progress down wards to the underground stem and to the root system. The infection starts at main root or at feeder root. The leaves become yellow and defoliate. The disease is managed by the following integrated management practice:

- Selection of healthy nursery material
- Provide good drainage
- Soil drenching with 1% Bordeaux mixture after removal of the affected plant
- Spraying with 1% Bordeaux mixture (or) COC 0.25% (or) Alitte 0.3%

- Soil application of neem cake and *Trichoderma viride or P. fluorescens*

Fig. 5.54: Black pepper vine affected by quick wilt

Stunt disease: This disease is caused by viruses. The vines show reduced internodes and the leaves become small, narrow and leathery. There will be gradual decline in the yield. Disease spreads through infected cuttings and also transmitted through insect vectors such as aphids and mealy bugs.

Management

• Use planting material free from virus

• Frequent inspection and destruction of infected plants

• Insect control by spraying insecticides such as dimethoate (0.05%).

Slow decline (slow wilt): Symptoms of this disease include leaf yellowing, defoliation and die-back. Feeder root are affected due to nematode infestation. Nematodes, such as *Radopholus similis* and *Meloidogyne incognita,* infestations result in necrosis and development of root galls and feeder root rotting.

Management

The pits are treated with granular insecticides or neem cake at the time of planting.

Activities

Processing of Black pepper

Materials required

Black pepper spikes, net bag or a perforated vessel, vessels, stove for boiling water, tarpaulin

Procedure

- Separate the berries from the spikes
- Tie them in a net bag
- Boil water in a vessel
- Dip the berries in the bag in boiling water for one minute
- Drain water and sundry the berries on a tarpaulin or cement floor

Check Your Progress

A. Fill in the Blanks

1. Pungency in black pepper is due to presence of _____.
2. Two major pepper producing states in India _____and_____ .
3. The supporting trees used for black pepper are referred as_____.
4. The spacing adopted for sole crop of black pepper is _____.
5. Chemical used in canned green pepper_____.

B. Multiple Choice Questions

1. Flowers in Black pepper are borne on the following type of branches.
   a) Orthotropic branches
   b) Plagiotropic branches
   c) Runners
   d) Main stem
2. Which of the following is a black pepper hybrid?
   a) Sreekara
   b) Kari munda
   c) Panniyur-1
   d) Pancham
3. Stage of harvesting for white pepper is
   a) One months before maturity
   b) One week before maturity
   c) When few berries in the spike are ripe
   d) Majority berries ripe

4. Recovery of dry black pepper is

   a) 15%

   b) 25-30%

   c) 30-35%

   d) 40-45%

5. Which of the following is a major disease of black pepper causing death of vines?

   a) Pollu disease

   b) Stunting

   c) Food rot / Quick wilt

   d) Leaf spot

C. Match the Columns

A	B
1) Erythina	A. Piperine
2) Pungency	B. Fully ripened berries
3) Plagiotrope	C. Standard
4) White pepper	D. Bush pepper

D. Subjective Questions

1) Write the climatic conditions required for pepper.

2) Explain propagation of black pepper.

3) Write a short note on bush pepper.

4) Write about the stages of harvest of black pepper for different products.

5) What is blanching? What are its advantages?

Module 6
Rhizomatous Spice Crop Cultivation

Module Overview

This module “Rhizomatous Spice Crop Cultivation" covers the essential techniques for growing spice crops like ginger, turmeric, and galangal. It includes guidance on soil preparation, irrigation, pest control, and harvest practices to maximize yield and quality.

Learning Outcomes

After completing this module, you will be able to:

- Understand rhizomatous spices, their growth requirements,
- Demonstrate harvesting and post-harvest handling methods to optimize the quality and yield of rhizomatous spices.

Module structure

- Session 1: Cultivate Rhizomatous Spices

Session 1: Cultivate Rhizomatous Spices

Turmeric

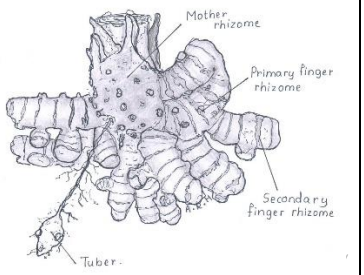
Botanical Name: *Curcuma longa* L.

Family: Zingiberaceae

Commercial Part: Rhizome or underground stem

Hindi: Haldi Bengali: Halud, Pitras Gujarati: Haldhar, Haldi Kannada: Arishia Konkani: Halad Malayalam: Manjal Marathi: Halede, Halad Oriya: Haldil Punjabi: Haldar, Haldhar, Haldi Sanskrit: Haladi, Harita Tamil: Manjal Telugu: Pasupu Urdu: Haladi

A versatile spice, turmeric is used as a condiment, dye, medicine, and cosmetic. It is utilized in religious rituals. India is the world's top producer and exporter of turmeric. With an annual yield of 11.02 lakh tonnes, it is grown on 2.94 lakh hectares. Some of the major states that cultivate turmeric include Telangana, Maharashtra, Karnataka, and Tamil Nadu.

		
Fig. 6.1: Turmeric plant	*Fig.* 6.2: Turmeric flower	*Fig.* 6.3: Rhizomes

Uses

Foods are flavoured and coloured using turmeric. It is a key component of curry powder. Curcumin, the colouring component isolated from turmeric, is utilized as an ingestible and natural colouring agent. The textile sector also uses turmeric as a dye. It possesses antibacterial qualities and is hence renowned for its ability to heal wounds. It is also used in cosmetics.

Climate and soil

In a variety of tropical conditions, from sea level to 1500 metres above sea level, turmeric can be cultivated under rainfed or irrigated circumstances with temperatures ranging from 20 to 35 °C. Although it may be cultivated in a variety of soil types, sandy or clay loam soils with a pH range of 4.5-7.5 and good soil organic matter are much suitable for growing.

Varieties

There are many cultivars that are be found in the country and they are typically identified by the name of the region in which they are grown. Turmeric cultivars such as Duggirala, Tekkurpet, Sugandham, Amalapuram, Erode local, Salem, Vaigaon, Alleppey, and Lakdong are some of the more well-known varieties. Several improved turmeric varieties, including IISR Prathibha, IISR Pragati, Roma, and Rajendra Sonia have been released from various institutions.

Cultivation

Preparation of land

The arrival of monsoon rains facilitates the land preparation. Three to four deep ploughings are required to give the soil a fine tilth. After receiving pre-monsoon showers, beds of 1.0 m in width, 30 cm in height and a convenient length are prepared with a 50 cm gap between each bed in locations with severe rainfall.

Creating ridges and furrows at a distance of 45 to 60 cm is another method of planting.

Seed material

For planting, finger rhizomes (main or secondary branches) and mother (the pseudostem's base) are employed. Each piece of rhizome should weigh around 40 gram. Mancozeb 0.3% is applied to the seed rhizomes for 30 minutes prior to planting and then they are dried in shade for three to four hours. For the planting of one hectare of turmeric, 2,500 kg of rhizomes must be used as the seed rate.

Transplanting

In this method, single bud sprouts (approximately 5 g) are raised into transplants in the pro-tray, which are then planted in the field after 30–40 days. The benefits of this method include the production of healthy planting materials and a decrease in the requirement of seed rhizomes which ultimately leads to lower seed cost.

Preservation of seed rhizomes

Rhizomes, for seed storage purpose, are typically heaped and covered with turmeric leaves in ventilated places. Alternatively, rhizomes can be stored in pits covered with hardwood planks having one or two holes for aeration. If scale infestations are seen, dip the rhizomes in a solution of quinalphos (0.075%) for 20 to 30 minutes. If fungi are present, dip the rhizomes in mancozeb (0.3%) to prevent storage losses.

Planting

In West Coast regions, where the rainy season starts early with pre-monsoon showers, the crop can be sown in April and May. Small pits are created on the beds with a 25 cm x 30 cm spacing. Well-decomposed compost or cow dung is used to fill pits. Seed rhizomes are then planted on top of the compost or manure and the soil is added. The ideal distance in ridges and furrows is 25 cm between plants and 45-60 cm between rows.

Manuring and Fertilizer Application

While preparing the soil for planting, apply farmyard manure (FYM) or compost at a rate of 30–40 tonnes per hectare by the method of broadcasting and ploughing or directly putting it in the planting pits. A hectare of turmeric should receive 60 kg of nitrogen, 50 kg of phosphorous, and 120 kg of potassium. While phosphorus is applied as a base fertilizer during planting, N and K fertilizers must be applied in three splits at 45, 90, and 120 days after planting (DAP). It is

advised to apply 25 kg of zinc sulphate as a basal fertilizer to soils with low zinc level. It's also advised to apply a micronutrient blend specifically made for turmeric as foliar spray (dose @ 5g/l) twice, 60 and 90 DAP, for higher yield.

Mulching

When planted in raised beds, the crop is immediately mulched with green leaves at a rate of 12–15 tonnes per hectare. Following weeding, fertilizer application and earthing up, mulching may be repeated at a rate of 7.5 tonnes per hectare at 40 and 90 days after planting.

Weeding and Irrigation

Depending on the weed growth, weeding needs to be done three times: 60, 90, and 120 days after planting. Depending on the weather and the soil type, irrigated crops require between 15 and 23 irrigations in clayey soils and 40 irrigations in sandy loams.

Mixed cropping

Turmeric can be cultivated as an intercrop with plantations crops such as coconuts and arecanuts. Cereals, onions, colocasia, chilies, and brinjal are few crops with which turmeric can be grown as mixed crop.

Fig. 6.4: Turmeric field

Harvesting and Processing

Depending on the kind and timing of seeding, turmeric is ready for harvest within seven to nine months after planting. This is shown by the drying of the leaves. The harvesting season typically lasts from January to March. The soil is dugged, the clumps are carefully lifted with a shovel, and the rhizomes are manually separated. It is also possible to harvest turmeric with a tractor and harvester. The gathered rhizomes are cleaned to remove any debris that has stuck to them.

Fig. 6.5: Harvesting of rhizomes

Processing

Boiling, drying, and polishing are steps in the processing or curing of turmeric. Turmeric is boiled within 3 to 4 days after harvest. Because the bulbs take a little longer to cook than the fingers, they are separated and cured separately. The dry recovery of turmeric varieties ranges from 19 to 23%.

Boiling

In this process, firstly the fresh rhizomes are cooked in water until they are soft and then they are dried. Boiling helps in killing the fresh rhizomes, removing the raw odour, hastening the drying process and producing an evenly coloured product. For boiling turmeric, the conventional method uses a kettle made of galvanised iron sheet. The turmeric rhizomes are boiled until froth forms and white fumes, with a distinctive odour, escape from the pan. Boiling is said to be finished, when a pointed stick with a light pressure gets inserted into the rhizomes. For fingers, the boiling process takes 45 to 60 minutes, while it takes 90 minutes for mother rhizomes. The quality of the rhizome is shown to be impacted by both overcooking and undercooking.

Fig. 6.6: Boiling of rhizomes

Fig. 6.7: Boiled rhizomes

Fig. 6.8: Dried polished rhizomes

Drying

The cooked fingers are spread out in layers, 5-7 cm thick, on the drying floor and allowed to dry in the sun. A thin layer is undesirable since it could negatively influence the colour of the dried product. The material should be piled or covered at night. The rhizome may need 10 to 15 days to dry entirely. The bulbs and fingers are dried separately.

Polishing and Colouring

Turmeric, that has been dried, has a poor appearance, a rough dull exterior covered with scales, and root fragments. The appearance is enhanced by either mechanically or manually rubbing the exterior surface. The dried turmeric fingers are polished manually by rubbing them against a firm surface. Power-operated drums can also be used to polish turmeric. Turmeric rhizomes are polished at industrial scale using large polishing devices with a batch polishing capacity of 500 to 1000 kg. Each batch takes roughly 45 to 60 minutes. The price of the produce is influenced by the colour of the processed turmeric. Thus, during the final polishing stage, turmeric powder is sprinkled to produce an attractive result.

Cleaning, grading, packing and storage

Three types of turmeric are distinguished in the trade:

Fingers: Before curing, the lateral branches or secondary "daughter" rhizomes are severed from the mother rhizome. Typically, fingers have diameter more than 1 cm and length between 2.5 and 7.5 cm.

Bulbs: These are central "mother" rhizomes, which have an oval shape, are shorter and have a bigger diameter than the fingers.

Splits: To aid curing and subsequent drying, bulbs have been cut into halves or quarters.

Material that has been cleaned and graded is often placed in new double burlap gunny bags and kept over wooden pallets in a cool, dry location shielded from light.

Pests and Diseases

Insects-Pests

***Conogethes punctiferalis* (Shoot borer)** larvae feeds on the internal tissues by boring into pseudo stems. A clear sign of a pest infestation is the appearance of a bore-hole on the pseudo stem, through which frass is ejected, and the wilted central shoot. Spray lamda-cyhalothrin (0.0125%) or malathion (0.1%) at intervals of 21 days from July to October. Start spraying as soon as the innermost leaf displays the first signs of a pest infestation.

Rhizome scale (*Aspidiella hartii*) is an insect that infests rhizomes both in storage and in the field (during the final stages of the crop). They feed on sap. When the rhizomes are heavily infested, they become shrivelled and dried, which affects their sprouting. If the infestation persists, treat the seed material with quinalphos (0.075%), for 20–30 minutes, both before storing and before sowing.

Diseases

Leaf blotch (*Taphrina maculans*): This disease first manifests as small, irregularly shaped, brown patches on either side of the leaves that quickly turn dirty yellow or dark brown. In extreme circumstances, the plants seem burnt and the rhizome yield is lower. Mancozeb 0.2% can be sprayed against the disease to control it.

Leaf spot (*Colletotrichum capsici*): This disease manifests as brown dots of varied sizes on the upper surface of young leaves. The spots have uneven shapes and have a white or grey centre. Furthur, two or more spots could combine to form an uneven patch that would cover almost the entire leaf. The damaged leaves gradually wither away. Rhizomes don't grow well at all. Spraying copper oxychloride (0.2%), Mancozeb (0.2%), or Carbendazim (0.5 kg/ha) can suppress the disease.

Rhizome rot (*Pythium aphanidermatum*): This disease causes the lower leaves of the diseased pseudo stem to turn yellow and the collar region to become soft and water-soaked. This causes the pseudo stem to collapse and the rhizomes to rot. The disease can be avoided by applying Mancozeb 0.3% to the seed rhizomes for 30 minutes both at the time of sowing and before storage. When the

disease is noticed in the field, COC 0.2% or Metalaxyl -Mancozeb 0.125% should be sprayed on the beds.

Fig. 6.9: Ginger plant

Fig. 6.10: Ginger inflorescence

Ginger

Botanical Name: *Zingiber officinale* Roscoe

Family: Zingiberaceae

Commercial Part: The rhizome

Indian Names: Hindi: Adrak Bengali: Ada Gujarati: Adu Kannada: Shunti, Ardraka Malayalam: Inchi Marathi: Ale Oriya: Ada Punjabi: Adrak Sanskrit: Ardraka Tamil: Inji Telugu: Allamu, Sonthi Urdu: Adrak, Adhrak

The rhizomes of ginger, a herbaceous plant, are used as a spice both in fresh and dry form. India is the world's top producer of ginger, with 1.67 lakh hectares producing 18.51 lakh tonnes of the spice. Ginger is grown in most of the states in India. However, Madhya Pradesh, Karnataka, West Bengal, Assam, and Orissa collectively account for 65% of the nation's overall production.

Uses

Food processing industries employ ginger oil, oleoresin, fresh ginger, dried ginger powder, and fresh ginger in various processed products. The pungency of ginger rhizomes is due to gingerol whereas the aroma is due to gingiberene. It is necessary for the production of ginger bread, confections, sauces and pickles, some cordials, ginger cocktails, carbonated beverages, liquors, curried meats and vegetables. It serves as a stimulant and carminative in medicine. It has more

extensive uses in traditional remedies. In soft drinks, ginger oil is used to impart flavour.

Climate and soil

Ginger can be grown from sea level to an altitude of 1500 m above sea level. It does well in warm and humid climates and may be cultivated in both irrigated and rain-fed environments. For the crop to be successfully grown, it is essential to have moderate rainfall at planting time until the rhizomes sprout, moderately heavy and evenly spaced showers during the growing season, and dry weather for about a month prior to harvest. The crop thrives in a temperature range of 19°C to 28°C with a humidity of 70–90%.

Ginger grows best in well-drained soils like sand, clay, red, or lateritic loam. Ideal soil for growing ginger should have a friable loam, rich in humus, and has a pH of 6.0 to 6.5. However, ginger should not be grown in the same soil year after year as it is an exhausting crop.

Varieties

In India, different ginger-growing regions produce a variety of ginger cultivars, most of which bear the names of the regions in which they are raised. Indigenous cultivars including Maran, Kuruppampadi, Ernad, Wayanad, Himachal, and Nadia are some of the most well-known. Among growers, the exotic cultivar "Rio-de-Janeiro" has become popular. There are several improved varieties of ginger. Among them, IISR Varada type is best for fresh ginger, dry ginger, and to make sweets whereas, IISR Rejatha is rich in essential oils.

Season

The first two weeks of May, when there are pre-monsoon showers, are ideal for planting ginger along India's west coast. It can be planted well in advance in the middle of February or early March when there is irrigation. By planting early, a larger yield is obtained and the likelihood of disease is decreased.

Land preparation

To bring the soil to a fine tilth, the field must be ploughed four to five times or dug deeply after receiving early summer showers. A 50 cm interspace is provided between beds that are prepared with dimensions of roughly 1 m in width, 30 cm in height, and a convenient length. For an irrigated crop, ridges are constructed at intervals of 40 cm. It is advised to solarize beds for 40 days using clear polythene sheets in areas vulnerable to rhizome rot disease and nematode infestations.

Fig. 6.11: Bed preparation for planting ginger

Fig. 6.12: Ginger field

Planting

Rhizome bits, known as seed rhizomes, are used to propagate ginger. One or two healthy buds are present on each pieces, 2.5 – 5.0 cm long and 20 –25 gm, of carefully selected seed rhizomes. The seed rate varies depending on the cultivation technique used. The seed rate is around 1500 to 1800 kg/ha. The seed rate might range from 2000 to 2500 kg/ha at higher altitudes. Mancozeb 0.3% (3 g/L of water) is applied to the seed rhizomes for 30 minutes after which they are dried in shade for 3-4 hours. The treated rhizomes are, then, planted at a distance of 20–25 cm along the rows and 20–25 cm between the rows. The seed rhizome bits are planted in hand-dug shallow pits that are covered with well-decomposed farmyard manure and a thin layer of soil that is then levelled.

To provide high-quality planting material at a lower cost, a transplanting method for ginger employing single bud sprouts (approximately 5 g) has been standardized. Ginger transplant yield levels are comparable to those of traditional planting methods. In this method, single sprout seed rhizomes are raised into transplants in a pro-tray and planted in the field after 30–40 days. The benefits of this technology include the production of healthy planting materials, a decrease in the quantity of seed rhizomes, and ultimately lower planting material costs.

Manuring

Well-decomposed farmyard manure must be applied at the time of planting, either by spreading it over the beds before planting or by applying it in the planting pits. Neem cake, applied at a rate of 2 tonnes per hectare during planting, aids in decreasing the prevalence of rhizome rot disease/nematode and improving production. Site-specific nutrient management based on the results of the soil test, for the major nutrients, is encouraged because the soil fertility

will vary depending on the soil type, agro ecological conditions, or management strategies. The usual fertilizer prescription is 100:50:50 kg NPK per hectare. P and K are applied in full at planting time, while nitrogen is applied in two split doses at 40 and 70 days after planting. At the time of sowing, green leaves are mulched at a rate of 10 to 12 tonnes per hectare. Green leaf mulching is to be repeated at 7.5 tonnes per hectare following weeding, fertilizer application, and earthing up after 45 and 90 days of planting.

Irrigation

In places with high rainfall (uniform distribution for 5 to 7 months), ginger is grown as a rainfed crop, whereas areas with low rainfall (uniform distribution for less than 5 months), ginger is grown as an irrigated crop. Throughout its crop cycle, ginger needs 1300–1500 mm of water. Irrigation is essential during the stages of sprouting, rhizome initiation (90 DAP), and rhizome development (135 DAP). In a standard irrigation system, the initial irrigation should be applied right away after planting, and successive irrigations are applied at intervals of 7 to 10 days. Sprinklers and drip irrigation systems can also be used to increase yield and improve water use efficiency.

Inter cultivation

Depending on the severity of the weed growth, 2-3 hand weedings are required prior to each mulching and fertilizer application. When there is water stagnation, proper drainage pathways must be offered. Rhizomes must be earthed up to avoid exposure and to create enough soil volume for their free development. It is carried out at 45 and 90 DAP right after weeding and fertilizer application.

Inter cropping and Crop rotation

In ginger, crop rotation is necessarily practiced. The crops that are most frequently rotated with ginger are vegetables, tapioca, ragi, paddy, and maize. In Kerala and Karnataka, ginger is often planted as an intercrop with coffee, orange, coconut, and arecanut crops. However, crop rotation involving tomato, potato, chillies, brinjal, and peanut should be avoided since these plants serve as host for the bacterium *Ralstonia solanacearum* that causes wilt.

Fig. 6.13: Ginger in areca plantations

Fig. 6.14: Ginger in a net house

Harvesting

After planting, ginger takes 210–240 days to reach full maturity. After 180 days, ginger can be harvested for use as a vegetable. The matured rhizomes are, however, harvested at full maturity, or when the leaves turn yellow and begin to dry, in order to make dried ginger. One month prior to harvest, irrigation is discontinued, and the rhizome clumps are carefully dug up with a spade. Tractor or power tiller-drawn harvesters are also utilised in large-scale cultivation. The adherent soil, roots, and dry leaves from the rhizomes are carefully removed. Fresh green ginger is preferred for use in cooking in the domestic market of India. For export, two varieties of dried ginger—bleached and unbleached—are produced. The level of pungency, the amount of volatile oils, and the content of fibre are the three most crucial factors in determining if ginger rhizomes are suitable for a given processing application. The fresh rhizome's level of maturity at harvest determines the relative amount of these three components.

Processing of ginger

The two main steps in the processing of ginger to produce dry ginger are

1. Peeling the ginger rhizomes to remove the outer skin
2. Sun drying to a safe moisture level

Stage of Harvest of Ginger for Various End Uses

End use	Stage of harvest (months after planting)
Vegetable purpose and preparation of ginger preserve, candy, soft drinks, pickles and alcoholic beverages	5-6
Dried ginger and preparation of ginger oil, oleoresin, dehydrated and bleached ginger	7-8

Fig. 6.15: Harvested rhizomes

Fig. 6.16: Peeled dried rhizomes

Peeling

Peeling helps with drying by removing the scaly epidermis. The drying process is hastened by using bamboo splits with pointed ends to scrape the outer skin off of fully developed rhizomes. Avoid using deep knife scraping so to protect the oil-bearing cells that are found immediately below the outer skin. Before drying, the peeled rhizomes are cleaned. The aroma, flavour, and pungency of the dry ginger prepared in this manner are excellent. When compared to Jamaican gingers, which are cleanly peeled, Indian dried gingers are typically rough peeled. Only the flat sides of the rhizomes are peeled and a large portion of the skin between the fingers is left untouched. The majority of the ginger produced is of this quality and is known as rough peeled or unbleached ginger.

Drying

Fresh ginger, when harvested, has a moisture level of roughly 80–82% but it is brought down to 10% for safe storage. In open yards, ginger is often sun-dried

in a single layer over a period of 8 to 10 days. The surface of the sun-dried ginger is unevenly wrinkled and dark in colour. Depending on the cultivar and growth conditions, the production of dry ginger ranges from 19 to 25 percent of fresh ginger.

Bleached ginger

To make bleached ginger, scraped fresh ginger is dipped in a slurry of slaked lime, Ca $(OH)_2$ (1 kg of slaked lime/120 kg of water), and then dried in the sun. The ginger is once more dipped in the slurry while the water present on the rhizomes dries. Until the rhizomes' colour is uniformly white, this practice is repeated. The same method can be used to bleach dry ginger. Ginger that has been limed has a nicer appearance and is less vulnerable to insect pest attacks while being stored and transported.

Polishing and grading

To get rid of the dry skin and wrinkles that are formed on the surface while drying, dried ginger is polished. It is accomplished by rubbing against a hard surface. After being cleaned, the ginger is physically graded according to the size of the rhizome, its colour, form, and the amount of residual lime (in the case of bleached ginger).

Storage

Dry ginger that has been packaged in gunny bags is very likely to become infested with storage beetles. Rhizomes that have completely dried out can be kept in sealed containers made of high-density polyethylene. Its aroma, flavour, and pungency would deteriorate if rhizome is stored more than two years.

Pests and Diseases

Insects-Pests

The most dangerous insect pest of ginger is the **shoot borer (*Conogethes punctiferalis*)**. The larvae feed on internal tissues as they burrow into the pseudostems causing the leaves to turn yellow and dry out. A typical sign of pest infestation is the existence of a bore-hole on the pseudostem, through which frass is ejected, and the withered and yellow central shoot. Spraying malathion (0.1%) at 21-day intervals from July to October will control the shoot borer.

Rhizome scale (*Aspidiella hartii*), is an insect that infests rhizomes both in the field (during later stages) and in storage. When the rhizomes are heavily infested they become shrivelled and dried which affects its sprouting. They feed on sap. Rhizome scale can be controlled by harvesting rhizomes at the right time,

removing seriously contaminated rhizomes, and treating seed rhizomes with quinalphos (0.075%) (for 20–30 minutes) before storage and even before planting.

Diseases

Soft rot (*Pythium aphanidermatum* and *P. myriotylum*): The most devastating disease to affect ginger, soft rot, causes the complete loss of affected clumps. The pseudostem's collar region is where the infection first appears and it spreads both upward and downward. As the rotting extends to the rhizome, the collar region of the damaged pseudostem becomes water soaked, resulting in soft rot with a distinct foul smell. Later on, root infection becomes apparent as well. Foliar symptoms start out as a slight yellowing of the margins of lower leaves, which extends to the leaf lamina over time. Since the disease is also seed borne, seed rhizomes should be chosen from disease-free gardens. The incidence of the disease can be decreased by treating seed rhizomes for 30 minutes with Mancozeb 0.3% or Metalaxyl+ Mancozeb 0.125% before storage and once more before planting, and then drenching at 30 and 60 days after planting. Since water stagnation predisposes the plant to infection, cultural activities including choosing well-drained soils for planting are crucial. Before planting, the soil can be solarized by covering the moist soil with a clear polythene film for 45–50 days. Application of *Trichoderma harzianum* coupled with 1 kg of neem cake per bed aids in lowering disease incidence.

Fig. 6.17: Ginger plant affected by soft rot

Bacterial wilt (*Ralstonia solanacearum*): The south west monsoon season is when bacterial wilt, a disease spread by soil and seed, appears. Water-soaked patches start to develop at the pseudostem's collar and move up and down the pseudostem. The first noticeable sign is a slight drooping and curling of the lower leaves' margins which extends upward. The plants display severe symptoms of wilting and yellowing in the advanced stage. Rhizomes eventually decay and emit

a foul smell. For the management of bacterial wilt, use the same cultural methods and seed rhizome treatment that are used for soft rot management. Ginger should not be planted in the same field repeatedly every year. Avoid areas where potatoes or other solanaceous crops are grown.

Asafoetida

Botanical Name: *Ferula asafetida*

Family: Apiaceae

Commercial Part: Oleogum resin extracted from rhizome and thickened root

Indian Names: Hindi: Hing, Bengali: Hing, Gujarati: Hing, Kannada: Ingu, Kashmiri: Yang, Malayalam: Kayam, Marathi: Hing, Oriya: Hengu, Punjabi: Hing, Sanskrit: Badhika, Agudagandhu, Tamil: Perungayam, Telugu: Inguva, Ingumo Urdu: Hing

Fig. 6.18: Asafetida plant

Fig. 6.19: Flowering stage

Asafoetida, often known as "Devil dung" and "Food of gods", is dried latex that is extracted from *Ferula asafetida* rhizomes. It is an important condiment and a spice with high value. Its cultivation is only restricted in cold, arid regions of west Asia. Each year, The first institute to introduce asafetida for growing in India was the CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur. Cold desert regions of India, including Lahaul and Spiti (Himachal Pradesh), Ladakh (Kashmir), and portions of Uttarakhand and Arunachal Pradesh, have been identified for asafoetida cultivation.

It is oleo gum resin that is extracted from the plant's stem and root. Its strong odour and stinky smell make it unpleasant in its purest form. To prepare it for consumption, flour and edible gum are combined together. The acrid taste and displeasing pungent odour is due to the presence of sulphur compounds. Extract from asafoetida includes resins (40–60%), gums (25 %), and volatile oils (10–17%). The main components of oil are disulphides, which are sulphur-containing chemicals, which give the substance its very unpleasant smell.

Perennial asafoetida grows to a height of 1 to 1.5 metres and has large carrot-shaped roots. Both male and female plants are produced by these rhizomes. The female plant has only leaves and no inflorescence whereas the male plant produces inflorescence. The underground rhizome of the female plants secretes an exudation in the form of a very viscous and sticky sap.

Uses

Asafoetida is used to flavour pickles, curries, and sauces. Because of its antibacterial qualities, it is also utilized in medications. Additionally, it is a pesticide used in organic farming. By enhancing digestion, it relieves bloating, acidity, and flatulence.

Varieties

Asafoetida comes in two primary types: Hing Kabuli Sufaid (Milky White Asafoetida) and Hinglal (Red Asafoetida). While the dark or black variety is oil soluble, the white, pale variety is water soluble.

The cultivars are divided into groups according on where they were grown, such as Irani Hing from Iran and Pathani Hing from Afghanistan. By introducing 6 accessions (EC966538, EC968466, EC968467, EC968468, EC968469, EC968470) on a trial basis, the CSIR-IHBT (Indian Institute of Himalayan Bioresources Technology), Palampur, Himachal Pradesh, is boosting the cultivation of hing farming in India and reducing its reliance on import.

Soil and Climate

Asafoetida favours fertile sandy loam or clay soils with good drainage. It can thrive on poor and light soils. It can tolerate both acidic to basic soil types. The climatic conditions of the cold desert region, with temperatures ranging from 20 to 30 °C and occasionally even higher, are excellent for asafoetida cultivation. For maximum growth, it needs dry, temperate conditions. It can be grown between 600 and 2400 metres above sea level. Crop growth will be negatively impacted by prolonged and heavy rainfall. It needs an average of 250–350 mm of rainfall per year. Its vegetative growth requires a temperature range of 10–20 °C. The ideal temperature for asafoetida germination is 15 °C. It cannot tolerate shade and needs enough of sunlight.

Propagation and Nursery management

The seed is the most effective way to propagate asafoetida. Its seeds have a protracted dormancy period and poor seed germination. Therefore, cold stratification is necessary to enhance seed germination. The embryo dormancy can be broken by exposing seeds to a temperature of 4°C for 60 days. In

comparison to spring plantings, seeds sown in the winter, between December and January, had a higher emergence percentage and a higher tuber yield.

Fig. 6.20: Asafetida seeds

In trays or polybags, the seeds are place in the medium at a shallow depth. When the seedlings are large enough to handle, they should be taken out and planted into individual pots. After that, they are planted in the soil.

Planting

The soil is ploughed and made to fine tilth. The seedlings are transplanted into the main field at 1.5 m x 1.5 m spacing once they are ready.

Manuring

It is advised to apply 15-20 tonnes per hectare of farmyard manure in the first year. The required fertilizer dosage for each plant is 20g N, 18g P_2O_5, and 25g K_2O. It is necessary to progressively increase the dose over ten years. Following the application of fertilizer, earthing up is necessary to ensure the mixing of fertilizer in the soil.

Irrigation

Asafoetida prefer moist environments only when the seeds are germinating. Later phases of water logging will be damaging. Since the crop is grown in high mountains, melting of snow in spring can supply the crop's water requirements. However, if drought conditions persist, spray or drip irrigation may be employed.

Inter-cultivation

Asafoetida requires extra attention in its early stages. For the plant to grow in a satisfactory manner, regular weeding is required. It is sufficient to weed twice a year (June - July and October - November).

Harvesting

In five years, the crop matures into trees that are 2m tall, and the roots and rhizomes of the plants produces latex gum. Older plants produce more as compare to newer plants. The ideal time to begin collecting the gum from the succulent stem and root is just before blossoming. The ideal months for harvesting the crop are March and April. Near the plant's roots, a vertical cut is made on the stem. For asafoetida extraction, roots with a diameter of 6 to 10 cm are suggested.

Fig. 6.21: Tools used for harvesting of resin

Fig. 6.22: Resin oozing from the rhizomes

Fig. 6.23: Removing solidified resin

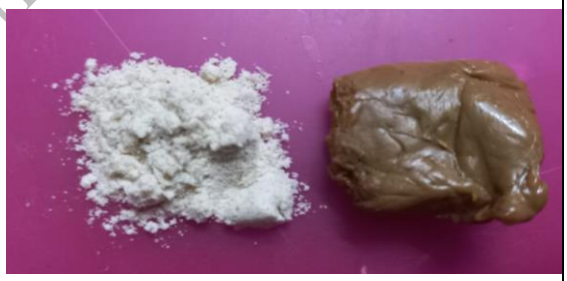


Fig. 6.24: Different forms of asafoetida available in the market

Tapping are carried out in stages. The top of the rhizome and the brush-like mass are covered with loose earth and gravel and left for 5 days after the yellow leaves have been removed. A little section of the top, measuring approximately 6 to 7 cm, is scraped away after the brushy mass on the rhizome's top is pulled out and the dirt and gravel surrounding it are cleaned. This is done after about 5 days. After scraping, three or four stones are placed along the border of the exposed rhizomes and one stone is placed on top to provide a form of cover or shade. The exposed surface oozes a milky substance. When this substance is exposed to air, it becomes harder which is then scraped and removed. The top of the rhizome is scraped off after two or three days, and the sap is then collected

for the first time. After gathering the sap or paste from the first scrap, the rhizome is scraped again at the same location underneath the first scrap, this time around 0.5 cm deeper. On the asafoetida stems, this procedure is repeated every 4-5 days until the gum stops oozing. It takes three months to finish the whole process. When fresh, the resinous gum is a greyish-white colour and when dried, it turns a rich yellow or amber colour.

Yield

On an average, a single plant yields around 40g to 900g of fresh gum.

Activities

Activity: I : Rhizome Transplant Technology

Material required: Turmeric rhizomes, cocopeat, Mancozeb, quinolphos, Plastic portrays, vermicompost, Trichoderma.

Procedure:

1. One month before planting, the seed rhizomes are cut into small piece of rhizomes weighing 5-7 g and having single bud.
2. Treat the single bud sprouts (mancozeb 0.3%) for 30 min before planting.
3. Fill the pro-trays (98 well) with nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched with Trichoderma 10g/kg of mixture.
4. Plant the turmeric bud sprouts in pro-trays.
5. Maintain the pro-trays under shade net house (50%).
6. Water the trays with rose can or by using suitable sprinklers.
7. Seedlings will be ready within 30-35 days for transplanting.

Activity: II: Processing of ginger

Materials required: Ginger rhizomes, stainless/ bamboo knife,

Procedure:

1. Select fully matured rhizomes
2. Scrape the outer skin with bamboo splits having pointed ends or stainless knife. Avoid deep scraping with knifes to prevent the damage of oil-bearing cells which are present just below the outer skin. The rhizomes are peeled only on the flat sides.
3. The peeled rhizomes are washed.

4. Sundry the rhizomes in a single layer in open yard which takes about 8 to 10 days for complete drying.

Check Your Progress

A. Fill in the Blanks

1) The planting material required for planting one-hectare turmeric crop is…
2) The colour of dried rhizome of turmeric is due to…
3) Economical part of turmeric is the …modification referred as rhizome.
4) Ginger belongs to the botanical family of …
5) An important step in processing of dry ginger is …
6) The Asafoetida, due to is odour is referred as…
7) The botanical name of asafoetida …

B. Multiple Choice Questions

1. Turmeric is valued for its use as
   a) Spice
   b) Dye
   c) Medicine
   d) All of these
2. Size of rhizome used for propagation of turmeric
   a) 5g
   b) 40g
   c) 100g
   d) 500g
3. Turmeric rhizome are killed by following process
   a) Peeling
   b) Slicing
   c) Boiling
   d) Chemical treatment
4. Origin of Ginger
   a) South-East Asia

b) South America

c) Mediterranean region

d) Africa

5. Exotic variety of Ginger is

a) Wynad

b) Rio de Janeiro

c) Manathodi

d) Varada

6. Which of the following is the most serious disease of ginger

a) Leaf spot

b) Soft rot

c) Leaf rust

d) Anthracnose

7. The resin of asafoetida is obtained from

a) Fruits

b) Flowers

c) Stem

d) Rhizomes

8. Area identified for cultivation of asafoetida in India

a) Jobner in Rajasthan

b) Lahaul and Spiti in Himachal Pradesh

c) Coonor in Tamil Nadu

d) Darjeeling in West Bengal

C. Match the Columns

A	B
1. Leaf blotch	A. Killing of rhizomes
2. Curcumin	B. Fungal disease

3. Boiling	C. Colouring pigment
4. Gingerol	D. Pungency
5. Gingeberene	E. Sulphur compounds
6. Hing Kabuli Sufaid	F. Milky white asafoetida
7. Hinglal	G. Aroma
8. Acrid taste of asafoetida	H. Red asafoetida

D. Subjective Questions

1. What are the uses of turmeric?
2. Describe the turmeric rhizomes harvesting and processing.
3. Describe the symptoms and management of soft rot of ginger.
4. Write a short note on bleached ginger.
5. What are the regions suitable for cultivation of asafoetida in India?
6. Write in brief about the propagation of asafoetida.

Answer Keys

Module 1: Weed Management in Spice Crops

Session 1: Manage weeds in Spice Crops

A. Fill in the Blanks

1. Jethro Tull
2. *Cyperus rotundus*
3. *Cichorium intybus*
4. Solanaceae
5. *Orobanche* Spp.

B. Multiple Choice Questions

1. (b) 2. (c) 3. (d) 4. (c)

C. Match the Columns

1. (c) 2. (b) 3. (a) 4. (d)

Session 2: Integrated Weed Management in Spice Crops

A. Fill in the Blanks

1. Drip
2. *Zygogramma*
3. Hand weeding
4. Chaining
5. Non-selective herbicide

B. Multiple Choice Questions

1. (b) 2. (a) 3. (a) 4. (a)

Module 2: Integrated Pest and Disease Management in Spice Crops

Session 1: Identify Major Insect-Pests of Spice Crops and their Management

A. Fill in the Blanks

1. Insecta
2. night
3. White Files
4. Ginger and Turmeric

5. Barrier
6. Head, Thorax and abdomen

B. Multiple Choice Questions

1. (b) 2. (d) 3. (c) 4. (c)

C. Match the Columns

1. (b) 2. (d) 3. (e) 4. (c) 5. (a)

Session 2: Identify Major Diseases of Spice Crops and their Management

A. Fill in the Blanks

1. Disease
2. damping off, wilt and rots
3. fungicide
4. 2.0-2.5 gm
5. *Taphrina maculans*

B. Multiple Choice Questions

1. (d) 2. (d) 3. (c)

Module 3: Herbal and Oil Yielding Spice Crops Cultivation

Session 1: Cultivate Herbal Spices

A. Fill in the Blanks

1. labiatae
2. Central Institute for Medicinal and Aromatic Plants
3. Rosemary
4. Spring to mid-summer
5. Seed, stem cutting and layering
6. Steam

B. Multiple Choice Questions

1. (a) 2. (b) 3. (c) 4. (a)

Session 2: Cultivate Oil Yielding Spices

A. Fill in the Blanks

1. Lamiaceae
2. Seed
3. Japanese mint
4. 6 weeks after
5. stolon

B. Multiple Choice Questions

1. (b) 2. (a) 3. (a) 4. (c)

Module 4: Seed Spice Crops Cultivation

Session 1: Cultivate Seed Spices

A. Fill in the Blanks

1. Apiaceae
2. Uttar Pradesh
3. 12 to 15 kg
4. Fennel
5. Kasuri type fenugreek
6. 2.0g/kg
7. Frost
8. 7-8%
9. *Anethum sowa.*
10. 6-8 kg/ha

B. Multiple Choice Questions

1. (c) 2. (b) 3. (a) 4. (d) 5. (a) 6. (b) 7. (c) 8. (a)

C. Match the Columns

1. (e) 2. (c) 3. (f) 4. (a) 5. (b) 6. (d) 7. (h) 8. (g)

Module 5: Tree and Pod Spices Cultivation

Session 1: Cultivation of Tree Spices

A. Fill in the Blanks

1. Bark
2. unopened flower bud
3. Eugenol
4. 11,000-15,000
5. *Myristica fragrans*
6. Mace
7. Dioecious
8. Seed
9. Mesocarp
10. Powdery mildew

B. Multiple Choice Questions

1. (b) 2. (c) 3. (c) 4. (a) 5. (c) 6. (b) 7. (d) 8. (b)

C. Match the Columns

1. (d) 2. (c) 3. (a) 4. (b) 5. (g) 6. (e) .7 (f) 8. (i) 9. (h) 10. (k) 11. (l) 12. (j)

Session 2: Cultivate Pod Spices

A. Fill in the Blanks

1. erect
2. Kerala
3. 15-20
4. IISR Vijeta
5. 50
6. Seophyte
7. 400-500 kg per hectare

B. Multiple Choice Questions

1. (b) 2. (c) 3. (c) 4. (a) 5. (b) 6. (c) 7. (d)

C. Match the Columns

1. (c) 2. (b) 3. (a) 4. (d) 5. (h) 6. (e) .7 (f) 8. (g)

Session 3: Cultivate Black Pepper

A. Fill in the Blanks

1. Piperine
2. Karnataka and Kerala
3. Standards
4. 3m x 3 m
5. sodium chloride (Common salt)

B. Multiple Choice Questions

1. (b) 2. (c) 3. (d) 4. (c) 5. (c)

C. Match the Columns

1. (c) 2. (a) 3. (d) 4. (b)

Module 6: Rhizomatous Spice Crop Cultivation

Session 1: Cultivate Rhizomatous Spices

A. Fill in the Blanks

1. 2500 kg
2. Curcumin
3. Stem
4. Zingeberaceae
5. Peeling
6. Devil dung
7. *Ferula asafetida*

B. Multiple Choice Questions

1. (d) 2. (b) 3. (c) 4. (a) 5. (b) 6. (b) 7. (d) 8. (b)

C. Match the Columns

(b) 2. (c) 3. (a) 4. (d) 5. (g) 6. (h) .7 (e) 8. (f)

Glossary

Antioxidant: A substance that protects cells from the damage caused by free radicals (unstable molecules made by the process of oxidation during normal metabolism). Free radicals may play a part in cancer, heart disease, stroke, and other diseases of aging.

Aromatic plants: Aromatic plants are a special kind of plants used for their aroma and flavour. Many of them are also used for medicinal purposes. Aromatic plants are from a numerically large group of economically important plants.

Broadcasting: Broadcast planting is the method of sowing seeds by scattering them over the surface of the soil. In this process, the seeds are scattered on the seedbeds either mechanically or manually. In the broadcasting method of sowing, the seeds are spread uniformly and are then covered with planking.

Bud: A small lateral or terminal protuberance on the stem of a plant that may develop into a flower, leaf, or shoot.

Compost: Compost is defined as a carbon-rich fertilizer derived from organic materials, including livestock manures, and other organic materials or mixed materials used to supply nutrients to soils. Compost is used to improve soil structure through the addition of carbon and provide plant nutrients

Crop residue: Crop residue is plant material remaining after harvesting, including leaves, stalks, roots.

Crop rotation: Crop rotation, the successive cultivation of different crops in a specified order on the same fields, in contrast to a one-crop system or to haphazard crop successions.

Deficiency: When plants don't have enough of a specific nutrient they may display a range of symptoms, varying from morphological impairments (i.e., stunting), to chlorosis or necrosis, to premature seed set and ripening. Deficiency in any given nutrient comes with the presentation a specific symptom or combination of symptoms.

Drainage: drainage, in agriculture, the artificial removal of water from land; drainage is employed in the reclamation of wetlands, in the prevention of erosion, and as a concomitant of irrigation in the agriculture of arid regions.

Farmyard manure: Farmyard manure refers to the decomposed mixture of dung and urine of farm animals along with litter and left-over material from roughages or fodder fed to the cattle.

Fertilizer: Fertilizer, natural or artificial substance containing the chemical elements that improve growth and productiveness of plants. Fertilizers enhance the natural fertility of the soil or replace chemical elements taken from the soil by previous crops.

Foliar spray: It is the application of fertilizers to foliage of the crop as spray solution is known as foliar spray. This method is suitable for application of small quantities of fertilizers, especially micronutrients. Major nutrients can also be applied by this method when there is no adequate moisture in top layer of soil.

Food preservatives: Food additives are substances added to food to maintain or improve its safety, freshness, taste, texture, or appearance. Food additives need to be checked for potential harmful effects on human health before they can be used.

Frost: Frost refers to an event where temperature falls to the point where ice forms inside plant tissues and causes damage to the cells.

Germination: Germination is usually the growth of a plant contained within a seed; it results in the formation of the seedling. It is also the process of reactivation of metabolic machinery of the seed resulting in the emergence of radicle and plumule.

Growing media: Growing media are materials that plants grow in. Growing media is specifically designed to support plant growth and can either be a solid or a liquid. Different components are blended to create homemade and commercial growing media. Different types of growing media are used to cultivate various plants.

Harrowing: The definition of harrowing is a soil preparation method that is often used in conjunction with plowing to ready a field for seeding. Harrowing is performed with a harrow, and it is sometimes confused with plowing, as they may appear similar at first, but plows go deeper into the soil and are typically wider.

Herb: any plant with leaves, seeds, or flowers used for flavouring, food, medicine, or perfume. "Bundles of dried herbs" any seed-bearing plant that does not have a woody stem and dies down to the ground after flowering.

Nursery bed: It refers to a land, which is made free from weeds, stumps, stones, pebbles, etc., and is used for sowing of seeds to raise seedlings and multiplication of different species of plants through asexual means.

Organic matter: Organic matter, organic material, or natural organic matter refers to the large source of carbon-based compounds found within natural and engineered, terrestrial and aquatic environments.

Pharmaceutical: Pertaining to pharmacy or the art of preparing drugs.

Plant propagation: Plant propagation is the process of increasing the number of plants of a particular species or cultivar. There are two primary forms of plant propagation: sexual and asexual. In nature, propagation of plants most often involves sexual reproduction, or the production of viable seeds.

Ploughing: The process of loosening and turning the soil is called ploughing (tilling). Before sowing the seeds, it is necessary to loosen and turn the soil in the fields as to break it to the size of the grains which is done with the help of three main implements or tools to plough are hoe and cultivator.

Rainfed: Rainfed agriculture is a type of farming that relies on rainfall for water. Rainfed agriculture includes both permanent crops (such as rubber, tea, and coffee) as well as annual crops (such as wheat, maize, and rice). For example, tubers, a staple crop for sub-Saharan Africa, have been all but uninfluenced by the technological developments of the green revolution.

Relative humidity: It is the ratio of actual water vapour content to the saturated water vapour content at a given temperature and pressure expressed in percentage (%). Diurnal variation in relative humidity: Mean maximum relative humidity occurs in the early morning.

Seedling: A seedling is a young plant that has been grown from a seed.

Spice: an aromatic or pungent vegetable substance used to flavour food.

Weedicides: chemicals sprayed over the fields to get rid of weeds. Some of the popularly used weedicides are 2, 4-d ethylester, neem extract, glyphosote, etc.

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