Course:	ENC	GG 364		Credit:	2(1+1)	Semester-VI
Course tit	le:	Protected Cultiv	ation and	secondary Ag	griculture	

Syllabus

Theory

Green house technology: Introduction, Types of Green Houses; Plant response to Green house environment, Planning and design of greenhouses, Design criteria of green house for cooling and heating purposes. Materials of construction for traditional and low cost green houses. Irrigation systems used in greenhouses, Important Engineering properties such as physical, thermal and aero & hydrodynamic properties of cereals, pulses and oilseed, their application in PHT equipment design and operation. Drying and dehydration; moisture measurement, EMC, drying theory, various drying method, commercial grain dryer (deep bed dryer, flat bed dryer, tray dryer, , re-circulatory dryer and solar dryer). Material handling equipment; conveyer and elevators, their principle, working and selection.

Practical

Study of different type of greenhouses based on shape. Study of Greenhouse Covering and Construction Materials. Study of Cooling System used in Green House. Study of Irrigation System used in Green House. Cost Estimation of Poly houses for 560 Sq.m Study of greenhouse equipment's. Visit to Commercial Green House. Visit to various Post Harvest Laboratories. Determination of Moisture content of various grains by oven drying & infrared moisture methods. Study of Grain Dryers. Study of Material Handling Equipments. Determination of engineering properties (shape and size, bulk density and porosity of biomaterials). Determination of Moisture content of various grains by Universal moisture meter. Field visit to seed processing plant.

Teaching Schedule

a) Theory

Lecture	Topic	Weightage
		(%)
1.	Green house technology - Green house technology:	6
	Introduction, History of green house, Advantages of green	
	house, Green house effect.	
2.	Types of Green houses -Types of Green houses:	7
	Green house type based on Shape, Utility, Construction and	
	Covering materials	
3.	Plant response to green house environment -Plant response to	6
	green house environment :	
	Light, Temperature, Relative Humidity, Ventilation and	
	Carbon di-oxide.	
4.	Planning and Design of green house - Planning and Design of	6
	green house: Site selection and orientation, structural design	
	and covering materials.	
5.	Materials of construction - Materials of construction for	6
	traditional and low cost green house: Wood, G.I., aluminum,	
	steel, R.C.C. and Glass	

Lecture	Topic	Weightage
		(%)
6.	Irrigation Systems used in green house - Irrigation Systems used in green house: Rules of watering, Overhead Sprinklers, Drip irrigation system and Foggers (Mist spraying)	6
7.	Design criteria of green house for Cooling and Heating purposes - Design criteria of green house for Cooling and Heating purposes: Cooling - Natural ventilation, forced ventilation Heating- Heating system, solar heating system, Water & Rock storage.	6
8.	Engineering Properties - Engineering Properties of cereals, pulses and oil seed. Their applications in PHT equipment design and operation: Physical properties: Size and Shape (Roundness and Sphericity) Porosity, Coefficient of friction, and angle of repose, Thermal properties: Definition of Specific heat and Thermal conductivity. Aero & hydrodynamic properties: Definition of Terminal velocity	6
9.	Drying and Dehydration - Drying and Dehydration: Definition of drying and dehydration, Utilities/Importance of drying Grain drying Theory- EMC definition, Thin layer drying and deep bed drying	6
10 & 11	Moisture Measurements- Moisture measurements: Moisture content and its measurement, Moisture content representation: Dry basis and wet basisMoisture Content determination Methods:- Direct methods- Air oven method, Vacuum oven method and Infra-red methodIndirect Methods- Electrical resistance method and Di-electric method.	12
12.	Various Drying Methods - Various Drying Methods: Sun drying, Mechanical Drying Mechanical Drying Methods:- Contact drying, Convection drying, Radiation drying	6
13.	Numerical on Moisture content and its representation- Numerical on Moisture content and its representation: Conversion of wet basis moisture contents to dry basis moisture contents Conversion of dry basis moisture contents to wet basis moisture contents, Problems on drying Problems on moisture contents Problem No.1 & No.2.	6
14 & 15	Commercial Grain Dryers - Commercial Grain Dryers: Construction and working principle - Deep bed dryer, Flat bed dryer, Recirculating dryer — (LSU and Baffle dryers), Tray dryer and Solar dryers	13
16.	Material Handling Equipments - Material Handling Equipment's: Construction and working principle- Conveyor- Belt conveyor and Screw conveyor Elevator- Bucket elevator	8
	Total	100

CONTENTS

		4.	Cultivation in greenhouse
Sr. No.	- Be 110,		Plant response to greenhouse environment; Light; Temperature; Relative humidity; Ventilation; Carbon
1.	Greenhouse		dioxide; Choice of crops for greenhouse cultivation.
	History of greenhouse; Greenhouse effect; Advantages of greenhouses; Classification of greenhouses; Greenhouse type based on shape; Lean-to type greenhouse; Even span type greenhouse; Uneven span type greenhouse; Ridge and furrow type greenhouse; Saw tooth type greenhouse; Quonset greenhouse; Greenhouse type based on utility; Greenhouses for active heating; Greenhouse for active cooling; Greenhouse type based on construction; Wooden	5.	Methods of greenhouse cooling; Ventilation; Ventilation with roof and side ventilators; Roof shading; Evaporative cooling; Fan and pad system; High pressure mist system; Low pressure mist system; Greenhouse irrigation systems; Rules of watering; Hand watering; Perimeter watering; Overhead sprinklers; Boom watering; Drip irrigation;
	framed structures; Pipe-framed structures; Truss framed structures; Greenhouse type based on covering material; Glass greenhouses; Plastic film greenhouses; Rigid panel greenhouses.	6.	Drying
	Planning and construction of greenhouse		Fluidized bed drying; Types of dryers; Deep bed dryers; Flat bed dryers; Continuous flow dryers; Recirculating dryers; Lousiana State University dryer; Fludised bed dryers; Rotary dryers; Spouted bed dryers; Tray dryers; Tunnel dryers.
	Glass.	7.	Storage Structures73
3.	Growth media per greenhouse crops		Existing storage methods; Requirement of good storage structures; Different storage structures; Bukhari type structure; Kothar type structure; Morai type structure; Bag storage structure; Cylindrical grain bin; Rectangular grain bin; Bunker storage; CAP storage structures.
	Organic matter; Inorganic coarse aggregates; Synthetic coarse aggregates; Pasteurization of root media; Steam pasteurization; Chemical pasteurization; Solarization treatment.	8.	Seed processing
,			Separation based on density or specific gravity of the material; Separation based on difference in shape and

surface texture of the material; Separation based on the basis of surface texture & stickiness properties of the grain; Seed size reduction; Principle of size reduction; Equipment for size reduction; Jaw crusher; Hammer mills; Ball mills.

A text book of Protected Cultivation and Post Harvest Technology



GREEN HOUSE

In the era of climate change, production of quality product in more quantity has become a challenge for scientists. These demands can be met when the environment for the plant growth is suitably controlled. The need to protect the crops against unfavourable environmental conditions led to the development of protected agriculture. Greenhouse is the most practical method of achieving the objectives of protected agriculture, where the natural environment is modified by using sound engineering principles for achieving optimum plant growth and yield.

1.1 History of Greenhouse:

A greenhouse is a framed or an inflated structure covered with a transparent or translucent material, in which crops could be grown under the conditions of at least partially controlled environment and which is large enough to permit persons to work within it to carry out cultural operations.

The growing of off-season cucumbers under transparent store for Emperor Tiberius in the 1st century, is the earliest reported protected agriculture. The technology was rarely employed during the next 1500 years. In the 16th century, glass lanterns, bell jars and hot beds covered with glass were used to protect horticultural crops against cold. In the 17th century, low portable wooden frames covered with an oiled translucent paper were used to warm the plant environment.

In Japan, straw mats were used in combination with oil paper to protect crops from the severe environmental conditions. Greenhouses in France and England during the same century were heated by manure and covered with glass panes. The first greenhouse in the 1700s used glass on one side only as a sloping roof. Later in the century, glass was used on both sides. Glasshouses were used for fruit crops such as melons, grapes, peaches and strawberries and rarely for vegetable production.

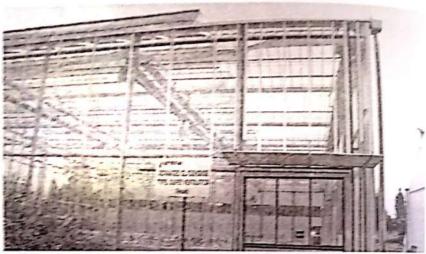


Fig.1.1 Advanced glasshouse (Courtesy: NETAFIM)

Protected agriculture was fully established with the introduction of polyethylene after the World War II. The first use of polyethylene as a greenhouse cover was in 1948, when Professor Emery Myers Emmert, at the University of Kentucky, used the less expensive material in place of more expensive glass.

The total area of glass houses in the world is estimated to be 40,800 ha and 63.24 % of these were found in North Western Europe. In contrast to glass houses, plastic greenhouses have been readily adopted in all five continents, especially in the Mediterranean region, China and Japan-According to 1987-88 estimates, an area of 1,91,500 ha, was under plastic greenhouses.

Table 1.1 Estimated greenhouse area (ha)

Sr. No.	Country	Area (ha)
1.	Crima	3,60,000
2.	Spain	55,000
3.	Japan	52,571
4.	Italy	26,000
5.	Koria	21,061
6.	Western North Africa	11,400

7.	Turkey	10,800
8.	The Netherlands	10,800
9	France	9,100
10.	United States of America	5,000
11.	Greece	4,620
12.	Middle East	4,300
13.	Germany	3,300
14.	Belgium	2,250
15.	United Kingdom	1,600
16.	Canada	1,470

Source: www.ag.arizona.edu/ceac/sites/ag.arizon

In India, the protective cultivation in plastic greenhouse is gaining popularity. Most of the farmers are cultivating flowers and exotic vegetables to meet the need of metropolitan /domestic market. As per 1994-95 estimates, approximately 100 ha. of land is under greenhouse cultivation.

Since 1960, the greenhouse has evolved into more than a plant protector. It is now better understood as a system of controlled environment agriculture (CEA), with precise control of air and roof temperature, water, humidity, plant nutrition, carbon dioxide and light. The greenhouses of today can be considered as plant or vegetable factories. Almost every aspect of the production system is automized, with the artificial environment and growing system under nearly total computer control.

1.2 Greenhouse Effect:

In general, the carbon dioxide in the atmosphere is 0.0345% (345 ppm). Due to emission of pollutants and exhaust gases into the atmosphere, the percentage of carbon dioxide increases which forms a blanket in the outer atmosphere. This causes the entrapping of the reflected solar radiation from the earth surface. Due to this, the atmospheric temperature increases, causing global warming, melting of ice caps and rise the ocean levels which result in the submergence of coastal lines.

The greenhouse covering material acts in a similar way, as it is transparent to short wave radiation and opague to long wave radiation.

During the daytime the short wave radiation enters into the greenhouse and gen reflected from the ground surface. This reflected radiation becomes long wave radiation and is entrapped inside the greenhouse by the covering material. This causes the increase in the greenhouse temperature. In it a desirable effect from point of view of crop growth in the cold regions.

This phenomenon of increase in the ambient temperature, due to the formation of the blanker of carbon dioxide is known as green house effect.

LF Advantages of greenhouses:

The different advantages of greenhouses for growing crops under commilled environment as listed below:

- I. The productions of the crop is increased considerably.
- Superior quality produce can be obtained as they are grown under suitable commilled environment.
- Four in five emps can be grown in a year in a greenhouse due to the availability of requiref plant environmental conditions.
- Cadges for efficient use of various inputs like water, fertilizers, seek and plant protection chemicals can be well maintained in a greenhouse.
- Effective commit of pesus and diseases is possible as the growing area is enclosed.
- 6. Percentage of germination of seeds is high in greenhouses.
- The acclimatization of plantless of tissue culture technique can be carried out in a greenhouse.
- Agricultural and horticultural corp production schedules can be planned to take advantage of the market needs.
- Different types of graving medium like pear-mass, vermiculate, rice hulls and compost that are used in intensive agriculture can be effectively utilized in the greenhouse.
- M. Expert quality produce of international standards can be produced in a greenhouse.
- Greenhouses are suitable for automation of infigurion, application
 of other inputs and environmental commits by using computers and
 artificial intelligence accomingues.

12. When the crops are not grown, drying and related operations of the harvested produce can be taken up utilizing the entrapped hear.

13. Self-employment for educated youth on farm can be increased.

1.4 Classification of greenhouses:

Greenhouse structures of various types are used successfully for crop production. Although there are advantages in each type for a particular application, in general there is no single type greenhouse, which can be considered as the best. Different types of greenhouses are designed to meet the specific needs.

Greenhouses are classified as follows:

1. Greenhouse type based on shape

- a) Lean-to type
- b) Even span type
- c) Uneven span type
- d) Ridge and furrow type
- e) Saw tooth type
- f) Quouses greenhouse

Greenhouse type based on utility

- a) Greenhouses for active hearing
- Greenhouses for active cooling

Greenhouse type based on construction

- a) Wooden framed structures
- Fige framed structures
- Truss framed structures

Greenhouse type based on covering materials

- a) Glass greenhouses
- Plastic film greenhouses
- Rigid panel greenhouses

These are briefly described in the following paras:

LA.1 Greenhouse type based on shape:

For this classification, the uniqueness of the cross section of the greenhouses can be considered as a factor. As the longitudinal section

tend to be approximately the same for all types, the longitudinal section cannot be used for classification. The cross sections depict the width and height of the structure and the length is perpendicular to the plane of cross section. Also the cross section provides information on the overall shape of the structural members, such as truss or loop, which will be repeated on every bay.

1.4.1.1 Lean-to type greenhouse:

When a greenhouse is placed against the side of an existing building a lean-to type greenhouse design is used. This design makes the best use of sunlight and minimizes the requirement of roof supports. The roof of the building is extended with appropriate greenhouse covering material and the area is properly closed.

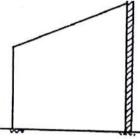
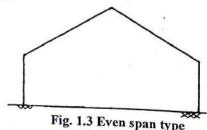


Fig 1.2 Lean-to type

1.4.1.2 Even span type greenhouse:

In this type, the two roof slopes are of equal pitch and width. This design is used for the greenhouse of small size and is constructed on levelled ground. Several single and multiple span types are available for use in various regions of India. For single span type, the span in general varies from 5 to 9 m, whereas the length is around 24m. The height varies from 2.5 to 4.3 m.



1.4.1.3 Uneven span type greenhouse:

This type of greenhouse is constructed on hilly terrain. The roofs are of unequal width, which make the structure adaptable to the side slopes of hill. This type of greenhouse is seldom used now-a-days as it is not adaptable for automation.

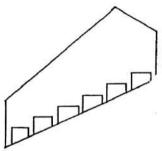


Fig 1.4 Uneven span type

1.4.1.4 Ridge and furrow type greenhouse:

Design of this type use two or more A-frame greenhouses connected to one another along the length of the cave. The cave serves as a furrow or gutter to carry rain and melted snow away. The side wall is eliminated between the greenhouses, which results in a structure with a single large interior.

Consolidation of interior space reduces labour, lowers the cost of automation, improves personal management and reduces fuel consumption as there is less exposed wall area through which heat escapes. The snow loads must be taken into account in the frame specifications of these greenhouses since the snow cannot slide off the roofs as in case of individual free standing greenhouses but melts away. In spite of snow loads, ridge and furrow greenhouses are effectively used in northern countries of Europe and in Canada and are well suited to the Indian conditions.



Fig.1.5 Ridge and furrow type

These are similar to the ridge and furrow type greenhouses except that, there is provision for natural ventilation. Specific natural ventilation flow path develops in a saw tooth type greenhouse.

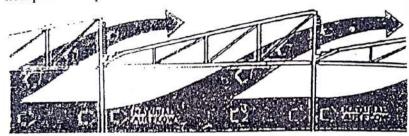


Fig 1.6 Saw tooth type greenhouse

1.4.1.6 Quonset greenhouse:

This is a greenhouse where the pipe arches or trusses are supported by pipe purlins running along the length of the greenhouse. In general polyethylene covering material is used for this type of greenhouse. Such greenhouses are typically less expensive than the gutter connected greenhouses and are useful when a small isolated cultural area is required.

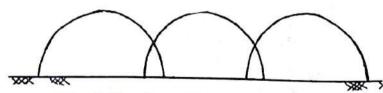


Fig.1.7 Interlocking ridge and furrow type Quonset greenhouse.

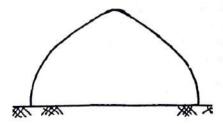


Fig.1.8 Free standing type Quonset greenhouse.

These houses are connected either in free standing style or arranged in an interlocking ridge and furrow. In the interlocking type truss members overlap sufficiently to allow a bed of plants to grow between the overlapping portions of adjacent houses. A single large cultural space thus exists for a set of houses in this type, an arrangement that is better adapted to the automation and movement of labourers.

1.4.2 Greenhouse type based on utility:

Of the different utilities, artificial cooling and heating of the greenhouse are more expensive and elaborate. Hence based on the artificial cooling and heating, greenhouses are classified as that uses active heating system and active cooling system.

1.4.2.1 Greenhouses for active heating:

During the night time, the air temperature inside greenhouse decreases and to avoid the cold bits to plants due to freezing, some amount of heat has to be supplied. The requirements for heating greenhouse, depends on the rate at which the heat is lost to the outside environment. Various methods are adopted to reduce the heat losses viz. using double layer polyethylene, thermopane glasses (two layers of factory sealed glass with dead air space) or to use heating systems, such as unit heaters, central heat, radiation heat and solar heating system.

1.4.2.2 Greenhouse for active cooling:

During summer season, it is desirable to reduce the temperature of greenhouse than the ambient temperatures, for effective crop growth. Hence suitable modifications are made so that large volumes of cooled air is drawn into greenhouse. This type of greenhouse consists of either evaporative cooling and with fan or fog cooling. The greenhouse is designed in such a way that it permits a roof opening of 40% and in some cases nearly 100%.

1.4.3 Greenhouse type based on construction:

The type of construction is predominantly influenced by the structural material, though the covering material also influences the type. Span of the house in turn dictates the selection of structural members and their construction. Higher the span, stronger should be the material and more structural members are used to make sturdy truss type frames. For smaller spans, simpler designs like hoops can be followed. Based on construction

greenhouses are classified as follows:

1.4.3.1 Wooden framed structures:

In general, for the greenhouses with span less than 6m, only wooden framed structures are used. Side posts and columns are constructed of wood without the use of a truss. Pine wood is commonly used as it is inexpensive and possesses the required strength. Timber locally available, with good strength, durability and machinability also can be used for the construction.

1.4.3.2 Pipe framed structures:

When the clear span is around 12 m, pipes are used for the construction of greenhouses. In general the side posts, columns, cross-ties and purlins are constructed using pipes. In this type also the trusses are not used. The pipe components are not inter connected but depend on the attachment to the sash bars for support.

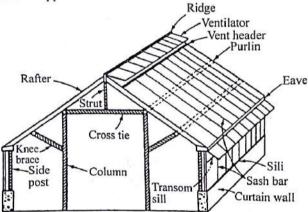


Fig.1.9 Pipe framed greenhouse structure.

1.4.3.3 Truss framed structures:

If the greenhouse span is greater than or equal to 15m, truss frames are used. Flat steel, tubular steel or angle iron is welded together to form a truss encompassing rafters, chords and struts. Struts are support members under compression and chords are support members under tension. Angle iron purlins running throughout the length of greenhouse are bolted to each truss. Columns are used only in very wide truss frame houses of

21.3 m or more. Most of the glass houses are of truss frame type, as these frames are best suited for pre-fabrication.

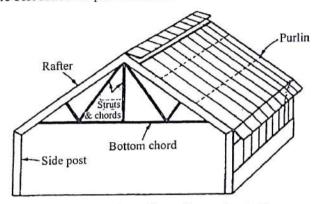


Fig.1.10 Truss framed greenhouse structure.

1.4.4 Greenhouse type based on covering materials:

Covering materials are the major and important component of the greenhouse structure. Covering materials have direct influence on the greenhouse effect inside the structure and they alter the air temperature inside the house. The types of frames and method of fixing also varies with the covering material.

1.4.4.1 Glass greenhouses:

Only glass greenhouses with glass as the covering material, existed prior to 1950. Glass as covering material has the advantage of greater interior light intensity. These greenhouses have higher air infiltration rate which leads to lower interior humidity and better disease prevention. Lean-to type, even span, ridge and furrow type of designs are used for construction of glass greenhouse.

1.4.4.2 Plastic film greenhouses:

Flexible plastic films including polyethylene, polyester and polyvinyl chloride are used as covering material in this type of greenhouses. Plastics as covering material for greenhouses have become popular, as they are cheap and the cost of heating is less when compared to glass greenhouses. The main disadvantage with plastic film is its short life as the covering material. For example, the best quality ultraviolet (UV) stabilized film

can be last for four years only. Quonset design as well as gutter-connected design is suitable for using this covering material.



Fig.1.11 Greenhouse made up by using plastic UV stabilized film.

1.4.4.3 Rigid panel greenhouses:

Polyvinyl chloride rigid panels, fiber glass-reinforced plastic, acrylic and polycarbonate rigid panels are employed as the covering material in this type of greenhouses. These panels can be used in the quonset type frames or ridge and furrow type frames. This material is more resistant to breakage and the light intensity is uniform throughout the greenhouse when compared to glass or plastic. High grade panels have long life even up to 20 years. The main disadvantage is that these panels tend to collect dust as well as to harbor algae, which results in darkening of the panels and subsequent reduction in the light transmission. There is significant danger of fire hazard.

EXERCISES

- Write a note on the history of protected agriculture and evolution of greenhouse.
- 2. What is greenhouse effect?
- 3. What are the advantages of using greenhouses?
- 4. Classify the greenhouses according to different criteria?
- 5. What is active summer and winter cooling of greenhouses?
- 6. Differentiate among wooden, pipe and truss framed structures.
- Write short notes on glass, plastic and rigid panel as greenhouse covering material.





PLANNING AND CONSTRUCTION OF GREEN HOUSE

2.1 Introduction:

A green house has basically one purpose of providing and maintaining a growing environment that will result in quality produce at maximum yield. The agriculture in the controlled environment is possible in all the regions irrespective of climate and weather. As an enclosing structure for growing plants, greenhouse must admit the visible light portion of solar radiation for plant photosynthesis and therefore must be transparent. At the same time to protect the plants, a greenhouse must be ventilated or cooled during the day because of the heat load from the radiation. The structure must also be heated or insulated during cold nights. A greenhouse acts as a barrier between the plant production areas and the external or general environment. Production is protected from external stresses such as weather and pollution from industrial and other sources. Hence while planning for greenhouse facility care must be taken in the selection of site and its orientation, in choosing the type of structural design and in the choice of covering material for better functioning and operation of greenhouses.

2.2 Site Selection:

A greenhouse is designed to withstand local wind, snow and crop loads for a specific cropping activity. In this way, the structure becomes location and crop specific. The following points should be considered for site selection:

- The building site should be as level as possible to reduce the cost of grading.
- ii. The site should be well aerated and should receive good solar radiation.
- iii. There should be good drainage of water on the selected site as there is

extensive use of water in greenhouse operations. Where drainage is a problem, it is wise to install tile drainage below the surface prior to the construction of greenhouse.

- iv. It is advisable to select a site with a natural wind break, such as a tree line or hill, on the north and northwest sides.
- v. In regions where snow is expected, trees should be 30.5 m away in order to keep drifts back from the greenhouses.
- vi. If trees are located on the sites, they should be located on the east, south or west side at a distance of 2.5 times their height.

2.3 Orientation:

The greenhouses can be orientated in North-South or East-West directions. However for getting maximum advantage of sunlight to the crops greenhouse should be oriented at North-South direction. By doing this the ventilation is also achieved in proper order, as the winds flow from the western side towards the greenhouse.

2.4 Structural Design:

The most important function of the greenhouse structure and its covering is the protection of the crop against hostile weather conditions (low and high temperatures, snow, hail, rain and wind), diseases and pests. Many types of greenhouse structures are successfully employed in protected agriculture and each type has its own advantages and is well suited for a particular case. It is important to develop greenhouses with a maximum intensity of natural light inside. The structural parts that can cast shadows in the greenhouse should be minimized, so the covering materials should have the largest possible unsupported area and consequently after the highest possible light transmittance. At the same time, greenhouse structures and structural components, including the covering should be strong enough to resist loads from snow, wind, crops and installations to provide adequate margins of safety to prevent structural damage or serviceability problems. A judicious component selection should be made since the light transmittance counteracts with the structural stability.

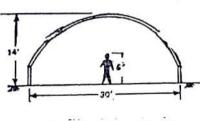
Loads in designing the greenhouse structures include the weight of the structure itself and if supported by the structure, loads of equipment for the heating, ventilation and water lines. The load may also include the weight of crops, if they are trained to a support system carried by the greenhouse

frame and also loads from wind and snow. Greenhouse structures should be designed to resist a 130 Km/hr wind velocity. The actual load depends on wind angle, greenhouse shape and size and the presence or absence of openings and wind breaks.

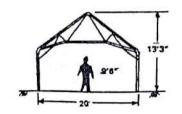
The ultimate design of a greenhouse consists of a balance of the following aspects.

- The overall structural design and the properties of the individual structural components.
- ii. The specific mechanical and physical properties which determine the structural behavior of the covering material.
- iii. The specific sensitivity of the crop to light and temperature to be grown in the greenhouse.
- iv. The specific requirements relevant to the physical properties of the covering material.
- v. The agronomic requirements of the crop.

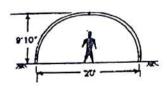
The different structural designs of greenhouse based on the types of frames are available.



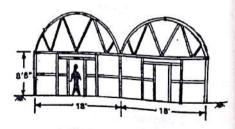
a. Side wall with arch roof.



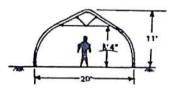
b. Side wall with gothic roof.



c. Hoop type roof.



d. Side wall with gutter connected roof.



e. Gothic arch frame roof.

Fig. 2.1. Structural design of different greenhouse frameworks.

A straight side wall and an arched roof (Fig.2.1 a) is possibly the most common shape for a greenhouse but the gable roof (Fig.2.1 b) is also widely used. Both structures can be free standing or gutter connected with the arch roof greenhouse. The arch roof and hoop style (Fig.2.1 c) greenhouse are most often constructed of galvanized iron pipe bent into its form by a roller pipe bender. If tall growing crops are to be grown in a greenhouse or when benches are used, it is best to use a straight side wall structure (Fig.2.1 d) rather than a hoop style house; this ensures the best operational use of the greenhouse. A hoop type greenhouse is suitable for low growing crops, such as lettuce or for nursery stock which are housed throughout the winter in greenhouses located in extremely cold regions. A Gothic arch frame structure (Fig.2.1 e) can be designed to provide adequate side wall height without loss of strength to the structure. This form of structure, along with others can be used as a single free standing greenhouse or as a large range of multi-span, gutter connected units.

2.5 Covering materials:

Various factors to be considered while selecting the greenhouse covering material are light transmission, weight, resistance to impact, durability to outdoor weathering and thermal stability over wide range of temperatures. The purpose for which the greenhouse facility is intended determines the selection of a covering material. For example, in temperate regions where high temperatures are required, the covering material with high light transmission and far IR absorption must be selected. Also the loss of heat by conduction should be minimum. Another important aspect in selection of covering material is the service life of material. A well maintained glass and acrylic sheet can last for many years, even up to 20 years or more. The poly carbonate and fiberglass- reinforced polyster sheet has a service life of 5 to 12 years. Of all the covering materials, polyethylene has the least service life of 2 to 6 months only, but when the

film is stabilized for UV rays, the life is extended to 2 to 3 years.

The following materials are used for covering of greenhouses.

- i. Polyethylene film
- ii. Polyvinyl chloride film
- iii. Polyester film
- iv. Tetzel T2 film
- v. Polyvinyl chloride rigid-panel
- vi. Fiberglass-oriented plastic rigid-panel
- vii. Acrylic and polycarbonate rigid-panel.

The ideal greenhouse selective covering material should do the following:

- It should transmit the visible light portion of the solar radiation which is utilized by plants for photosynthesis.
- It should absorb the small amount of UV in the radiation and convert a portion of it to fluorescence into visible light useful for plants.
- iii. It should reflect or absorb IR radiation which are not useful to plants and which causes greenhouse interiors to overheat.
- iv. It should be of minimum cost.
- v. It should have usable life of 10 to 20 years.

Such a covering material will obviously improve controlled environment agriculture performance, reducing solar heat load, increasing light levels and crop yields.

2.6 Construction materials for greenhouse:

Materials that are commonly used to build frames for greenhouse are wood, bamboo, steel, galvanized iron pipe, aluminium and reinforced concrete. Frames often incorporate a combination and alloys of these materials. The selection of these materials was based on their specific physical properties and requirements of design strength. Life expectancy and the cast of the construction materials also decide the selection of materials.

The construction materials are discussed in the following paragraphs.

2.6.1 Wood:

Wood and bamboo are generally used for low cost polyhouses. In

these houses, the wood is used for making frames consisting of side posts and columns over which the polyethylene sheet is fixed. The commonly used woods are pine and casurina, which are strong and less expensive. In pipe-framed polyhouses, wooden battens can be used in the end frames for fixing the covering material. In tropical areas, bamboo is often used to form the gable roof of a greenhouse structure.

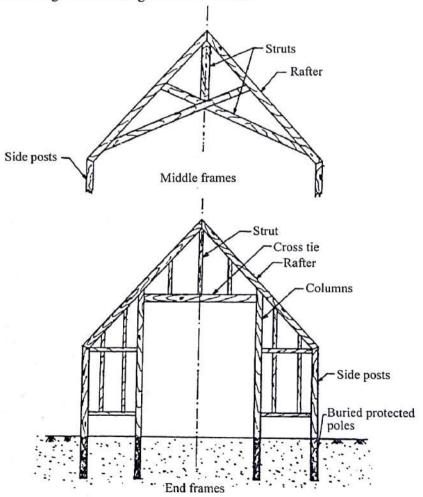


Fig. 2.2. Wooden scissors-truss type films plastic greenhouse.

The second second

Wood must be painted white to improve light conditions within the greenhouse, but care should be taken to select a paint that will inhibit the growth of mold. Wood must also be treated for protection against decay.

Special treatment should be given to the wood that may come into contact with the soil.

Chromated copper arsenate and ammonical copper arsenate are water based preservatives that are safe to use where plants are grown. Even natural decay resistance woods, such as red wood or cypress should be treated, in desert or tropical regions but they are expensive.

2.6.2 Galvanized iron, Aluminium, Steel and Reinforced Cement Concrete:

Galvanized iron (GI) and steel members are generally used in different frame works of greenhouse structure designs. In galvanizing operation the surface of iron or steel is coated with a thin layer of zinc to protect it against corrosion. Among many others, the two commonly followed procedures are

- i. Hot dip galvanizing (hot process) where the cleaned member is dipped in molten zinc, which produces a skin of zinc alloy to the steel.
- Electro-galvanizing (cold process) where the member is zinc plated similar to other forms of electro-plating.

As the wood is becoming scarce and more expensive, GI pipes, tubular steel and angle iron are used for side posts, columns and purlins. The galvanization process makes the iron rust proof, hence the common problem of rusting of iron structural members is eliminated. In the pipe frames, in general GI pipes are used as side posts, columns, cross ties and purlins. All the pipe components are not inter connected but depend on the attachment to the sash bars for support.

Often the frames may be all aluminium or steel or a combination of the two materials. Aluminmum and hot dipped GI are comparatively maintenance free. In tropical areas, it is advisable to double dip the steel, especially when the single dip galvanizing process does not give a complete cover of even thickness to the steel. Aluminium and steel must be protected from direct contact with the grond to prevent corrosion. If there is a danger of any part of the aluminium or steel coming into contact with the ground it must be thoroughly painted with bitumen tar.

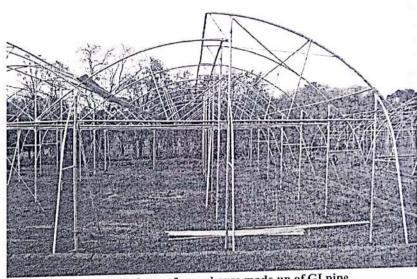


Fig. 2.3. Skeleton of greenhouse made up of GI pipe.

For truss frames, flat steel, tubular steel or angle iron is welded together to form a truss consisting of rafters, chords and struts. The angle iron purlins running throughout the length of the greenhouses are bolted to each truss. Now-a-days the greenhouse construction is of metal type, which is more permanent. While use of reinforced cement concrete is generally limited to foundations and low walls, concrete is sometimes used as support posts for frames made of bamboo. In permanent bigger greenhouses, floors and benches for growing the crops are also made of concrete.

2.6.3 Glass:

Glass has been the traditional glazing material all over the world. The most commonly used glass for greenhouse is the 'single drawn' or 'float glass', secondly the 'hammered' and 'tempered glass'. Single drawn glass is made in the traditional way by simply pulling the molten glass either by hand or by mechanical equipment. Float glass is made in modern way by allowing the molten glass to float on the molten tin. The single drawn or float glass has a uniform thickness of 3 to 4 mm. The term 'hammered glass' defines a cast glass with one face (exterior) smooth and the other one (interior) rough, designed so as to enhance light diffusion. Therefore, this glass is not transparent but translucent. The thickness of this type of glass

is usually 4 mm. The tempered glass is the glass, which is quickly cooled after manufacture, adopting a procedure similar to that used for steel. This kind of processing gives the glass higher resistance to impact which is generally caused by hail. Coating for glass, such as metal oxide with a low emissivity are used for saving of energy with adequate light transmittance. Such coatings are applied only to float glass.

Glass though fragile, is a strong material when it is used properly and loaded in the correct way. Glass used as a covering material of greenhouses is expected to be subjected to rather severe wind loading, snow and hail loading conditions. To limit the chances of breakage of glass coverings, design rules should be applied to the supporting structure of the glass panels. Such rules are aimed, in general, at limiting the deformation of the structural components which are supporting the glass panels.

Also, to provide the proper supporting conditions for glass panels, rules are given for the grooves in glazing bars. Different calculation methods are given for glass panels depending on whether they are supported on 2, 3 or 4 sides. The strength mainly depends on the length/width ratio of the panel and on the thickness of the panel but the most widely used thickness is 4 mm.

EXERCISES

- 1. What are the factors to be considered in site selection of greenhouses?
- 2. How the orientation of the greenhouse is done?
- 3. Describe different structural designs of greenhouses with neat sketch.
- What factors need to be considered while selecting the covering material for greenhouse.
- 5. List the features of an ideal greenhouse selective covering material.
- 6. Describe different materials used for construction of greenhouse.
- 7. How wood can be utilized as a construction material of greenhouse?
- 8. Write short notes on the following
 - a) Galvanized iron
- o) Aluminium

c) Steel

d) Reinforced cement concrete





GROWTH MEDIA FOR GREENHOUSE CROPS

3.1 Introduction:

Root media provides number of function in addition to support the above ground plants. Functions that often appear mutually exclusive as root respires, requiring oxygen and a means of eliminating CO₂. On the other hand, plants also require water and soil must provide water in abundance without adversely restricting aeration. The substrate must also supply adequate nutrition and the medium must be free from disease organism. To meet these basic requirements, soil is generally modified for greenhouse cultivation. Depending upon the species and location chosen, production may be directly in the ground, as is often the case with roses and carnations or tomatoes. The soil volume is essentially unrestricted. Drainage, leaching, nutrition, modification and disease control will be different from usual case of open field cultivation where, production occurs in restricted, shallow soil volume.

3.2 Principle:

Soil properties are desired from the size of individual particles composing the soil, the mineral composition of those particles, their structural arrangements, location and how the soil is manipulated.

The clay soils are having more surface area than that of gravel. Hence clay soils will usually retain more water at higher soil moisture suction than sandy soils. The clay or highly organic soils will be more resistant to radical chemical charges. Size alone, however has more of an effect on water retention properties than on chemical properties.

3.3 Chemical Properties:

The small of clay and humus particle referred to as micelles have a negative electrical charge. As a result, they will attract positively charged cations such as potassium, sodium, calcuim, magnesium and hydrogen. If fertilizer is added to the soil, the concentration of fertilizer salts increase in

25

the soil solution. Some of the cations are absorbed on the clay or orgainc matter and others are returned to the solution.

If concentration of one type of cation is reduced in soil solution, ions are released from the exchanger, tending to maintain a constant concentration of that cation in the solution. Cations are not equally attracted to the clay organic matter (exchanger), the are usually replaced in the order Na > K > Mg > Ca. It is generally said that soil is buftered or is resistant to change to absorb or store ions is measured by soils cation exchange capacity (CEC) and expressed as milliequivalent per 100 g of soil. The relative ability of different soils and amendments to store ions is given in Table 3.1, revealed that gravel or sand medium require precision in handling nutrition as there is no buffering action and small chemical addition will have immediate and marked effect.

Table No. 3.1 Relative cation exchange capacity (CEC) of common soil materials (Furuta, 1974)

Relative (CEC)		
10		
3		
1		
0.5 or less		
0		
15		
20		
14		
3		

3.4 Soil Structure:

Physical characteristics of greenhouse soils are probably more important than chemical properties. The primary soil particles clay, silt, humus, sand determine the soils texture and basic characteristics of water retention, aeration and chemistry. The root system is in intimate contact with these particles as shown in Fig.3.1. Some researchers have estimated root surface area of a single plant in 0.05m³ of soil to exceed 632 m² (Dittner, 1937). During the day when plants are loosing water, the liquid must be supplied to roots at rates sufficient to meet the needs. A large portion of

required nutrients is to be carried into the roots with flowing water.

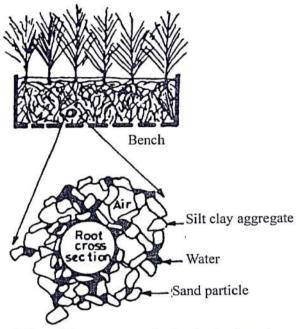


Fig. 3.1 Soil particle arrangements about a single root (Hanan *et al.* 1978)

Oxygen must be supplied to the roots through water films though films may not be continuous. As oxygen diffusion through water is 1000 time slower than through air, the thickness of water film around the root become critical (Hanan et.al. 1978). Thus, soil can be modified to provide a structure that permits adequate water and air supply. Water films around the roots can also be changed through irrigation practices or in shallow soil layers by changing the depth. The prime objective is to provide a macro structure such that water and air move through soil rapidly. But the aggregates composed of primary particles, retain sufficient amount of water and nutrients to meet requirement between irrigation and fertilization.

3.5 Properties of root medium:

In order to prepare a root media for furnishing the objective discussed earlier, a list of desirable properties of root media is given below.

3.5.1 Stability of organic matter:

Organic matter added to soil in the field decomposes and converts into humus which acts as a cementing agent to hold particles together in lumps or aggregates.

3.5.2 C:N ratio:

The amount of nitrogen (N2) in relation to carbon (C) in the root medium is important. The ratio for nitrogen to carbon should be 30:1 for decomposition of organic matter. If this ratio exceeds the desired limit, then the amount of nitrogen exists in soil or added as fertilizer will be consumed by the micro organism rather than by plants. It will result into improper decomposition of organic matter.

3.5.3 Bulk density:

It is important from the view point of supporting the plant in the soil. It varies from 640 to 1200 kg/m³ (0.64 to 1.2 gm/cc), for potting media after watering.

3.5.4 Moisture retention and aeration:

Proper moisture retention capacity and aeration are the important parameters of any root medium. Studies show that the water should occupy 35 to 50% pore space, whereas air should fill 10 to 20% after irrigation of

3.5.5 Cation exchange capacity(CEC):

It is a measure of the magnitude of negative electrical charge and is generally expressed as milliequivalent per 100 gram of dry root media.

Sandy

3 to 6 meg/100

Clay loom

10 to 25 meg/100

Organic matter:

250 to 450 meg/100

3.5.6 pH:

The pH level controls the availability of nutrients to the plant. The average level of availability for all essential plant nutrients exists in the pH range of 6.2 to 6.6. Thus, it becomes important to maintain a prescribed

3.6. Ingredients for root medium:

Soil, organic matter and coarse aggregates are blended together in definite proportion on volume basis to prepare a root medium which meets

the objective of growing a healthy plant. Some of these materials are discussed below.

3.6.1. Soil:

It is combination of clay, silt, sand and organic matter. Clay being the finest in size (0.002 mm) is responsible for most of the physical and chemical properties of soil. Composed of secondary hydrated aluminosillicates, in which isomorphic substitution have taken place, carry negative charge and react with charged particles. Soils of high clay content have a high water retention capacity with slow drainage hence aeration is a problem.

Silt particle vary in diameter from 0.002 to 0.05 mm, with large surface area, have a greater chemical activity than the coarse sand. Silt soils have relatively poor drainage. Unless supplemented by adequate amount of sand, clay or organic matter, the silt substrate is considered to be undesirable soil constituents as far as root media is concerned.

The sand particles range in size from 0.5 to 2.0 mm in diameter and due to large particle size they act as an individual particle. Sandy soils have large pore spaces thus negligible water and nutrient holding capacity and allow most of water to percolate inside the ground.

The water holding and nutrient retention capacity between soil of different texture are amended by mixing the organic matter, fertilizer & coarse aggregates in relation to texture of the soil. The pores within and between aggregates permit rapid drainage of water and gas exchange. Some of the ingredients required for preparation of root media outlined below.

3.6.1.1 Organic Matter:

The addition of organic matter makes the soil loose, open channels for rapid drainage of water and free movement of air. This also prevent close packing of individual soil particles and aggregates. Particularly, in sandy soils this type of amendment improve moisture retention capacity of soil. Proper selection of the organic component of the growing media is necessary to avoid the problem of ammonia toxicity after pasteurization.

Following materials are used as the organic matter component of growing media for greenhouse.

Peat and peat like structures:

The term peat-moss refers to several materials which are similar in

origin but vary distinct in their botanical composition and their physical and chemical characteristics. Peats are formed by the accumulation of specific plant materials in poorly drained locations. The type of plant materials and its degree of decomposition determine the extent at which peat should be used for root media preparation. Peat is, generally classified into four distinct types namely,

- i. Sphargnummons peat
- ii. Hyperaccon peat
- iii. Reed and sedge peat
- iv. Humus peat

Sphagnummons peat is the most popular form of organic matter for preparing root media. It consists of at least 75 percent of partially decomposed stems and leaves of sphagnummoss. The fibrons and sellular structure of the moss must be reorganiable and it should be essentially, free from decomposed colloidal residue, wood particles, silt and clay. On compression it should exhibit elasticity and sponginess. Use of this as a organic component, satisfy the root media requirement and can be mixed easily with other components and long lasting. Neither it adds appreciable amount of nutrients to the media nor decrease the available nutrients of the soil. Generally its nature is quite acidic but can be amended by applying lime store. After pasteurization biological and chemical charges do not occur.

The other matters used in root media are

- Manure wood residue
- 2. Saw dust
- Wood chips
- 4. Bark
- Corn cobs
- 6. Bagasse
- 7. Rice hulls
- 8. Straw
- 9. Coconut husk

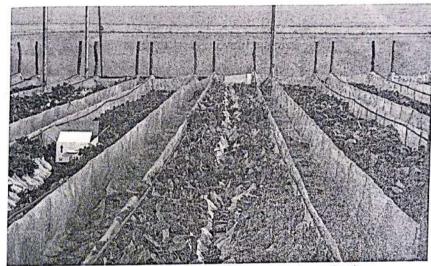


Fig.3.2 Coconut husk used as growth media for anthurium.

3.6.1.2 Inorganic coarse aggregates:

These materials are added to the root media to increase the porosity and improve the drainage and air movement activity. A list of few inorganic coarse aggregates is given below.

- 1) Sand: Size of particle is a determining factor for selection of sand as one of the component. Fine sand contribute little as far as improvements are required for drainage and air aeration but is low in nutrients and water holding capacity and is chemically and biologically inert.
- Perlite: It is produced from crushed alumina-silica volcanic rock. Its regular surface can retain water. Perlite is sterlite with a pH of 7 to 7.5, chemically inert and does not have cation exchange capacity (CEC). On mixing, it loosens the soil mixture, does not decay and reasonably resistant to abrasion.
- 3) Vermiculite: It has high nutrient and moisture retention capacity along with high cation exchange capacity (CEC). It contains large amount of potassium and magnesium which are available to plant. It is not durable and compressed and breaks easily in wet condition.
- 4) Calcined clay: These are porous and retain large quantities of nutrients and water. They do add very limited amount of nutrients for

the growth of plant. When mixed with other ingredients of root media, it creates large pore spaces which are durable and stable.

5) Cinders: Cinders are porous, light and possess a particle configuration which produces large pore spaces in mixture. Cinders may contain large quantities of easily leached sulphates. So presence of these sulphates require extensive leaching before mixing with root media for crop production.

3.6.1.3 Synthetic coarse aggregates:

Now a days several plastic materials are being used as one of the ingredients of root media. Either they are the byproducts of plastic manufacturing or prepared especially for the use as root media component. They are used most effectively as substitute for sand or perlite in a mixture prepared with sphagnummos peat or pine bark. Some of them are discussed below.

- 1) Expanded polystyrene flakes: It is a by-product of polystyrene bead processing. These are odorless, chemically neutral and decay resistant. The do not absorb water internally and hold a small quantity of water on the surface of the particle. Thus, it improves drainage aeration and decrease bulk density of growing medium.
- 2) Urea formaldehyde foam: These are specially prepared by mixing air with a liquid resin and allowing the mixture to cool under controlled temperatures. These are available in 2000 litre sacks in 50 cm x 100 cm blocks. The foam particles are like sponge which hold large quantity of water. The pH of this foam is about 3.0, it may further lower the particles and are subject to decompose.

3.6.2 Pasteurization of root media:

In the absence of crop rotation, the normal balance between soil organisms is disturbed, which result in the loss of fertility and hence soil borne pests and diseases multiply manifold to a great extent. The presence of pathogenic bacteria, fungi, insects, nematodes or weed seeds in the growing root media will interfere with the plant growing inside greenhouses. These parasitic organism attack root, stem of the plant which, in turn hamper the growth of crop to half of what it would be in healthy soil.

Pasteurization may be carried out by chemical fumigants and by applying heat in the form of dry heat or steam. Hot air is not preferred as

it contains relatively low heat and also drenches the medium. Dry heat is applied, occasionally to a moving mass of root media. Chemical fumigants do have limitation of availability and their variation is effectiveness for eradicating all soil pests. Growing media heated with chemicals should be aerated at least for 14 days before seeding.

The details of pasteurization methods is discussed in following sections.

3.6.2.1 Steam pasteurization:

The eradication of soil pests using heat treatment is based on the fact that living organism have relatively low thermal death points. The steam pasteurization is responsible for killing of considerable amount of beneficial organism in addition to pathogens. If weed seeds are not a major problem, then a temperature of 70°C for 30 minutes will eliminate soil pathogens which are harmful for greenhouses crop production. For a satisfactory pasteurization in commercial greenhouses, the recommended treatment is to raise the root media temperature to 82° C and maintain this for 30 minutes at the coolest point in the root media. Steam provides a very effective means of transforming a large quantity of heat i.e. 540 kcal/kg at a low intensity (100° C). Heat is transferred through steam until root media particles reach a temperature of 100° C. At this point, condensation stops and steam flows to low temperature zone. Consequently, most substrate particles will be heated to a temperature of 100° C before the coolest portion of the substract reach 82°C, which is recommended temperature for destroying soil pests.

Presence of moisture is the deciding factor of steam treatment. If moisture content is more, then more heat will be needed to evaporate moisture. On the other hand, proper eradication is not possible in low moisture content root media. Soil structure is also important as clay soil is most undesirable for steam pasteurization.

Some of the problems associated with the heat pasteurization are:

- Accumulation of toxic compounds, increase in soluble salts, maganeze toxicity and ammonia toxicity.
- 2) Recontamination.

3.6.2.2 Chemical pasteurization:

Soil fumigants are volatile chemical substances whose vapors diffuse

through the substract pores and act as toxicant to the soil pathogens. These fumigants do not release toxic quantities of magnese and soluble salts when applied to root media. However, in some cases, ammonia may accumulate due to eradication of nitrifying bacteria but no response on ammonifying organism. These are not preferred owing to their toxic nature harmful to plants and man. For effective fumigation, there is critical temperature requirement of 16 to 30° C soil temperature for most fumigants. At higher temperature activity of micro-organism would increase thus may not be that susceptible and also the rate of fumigation would be fast.

3.6.2.3 Solarization treatment:

For small volume of potting soil, moist soil is sealed in polyethylene bags, each holding 5 kg. of soil are kept on concrete or black polyethylene sheets for two weeks during summer. In the sealed polyethylene bags, water vapor and CO₂ accumulate, heat and moisture are conserved which result into greater mortality of nematodes. After solarization, the bags are cut open at one end and the seed or cutting is placed, alternatively soil may be used for potting or for nursery trays.

EXERCISE

- Q.1. What is the principle used for growth media for greenhouse crops?
- Q.2 What is the role of soil structure in the root media?
- Q.3 What are different properties of root media
- Q.4 Describe the different ingredients used for root media.
- Q.5 Describe different methods used for pasteurization of root media.





CULTIVATION IN GREENHOUSE

Number of crops can be grown in the greenhouse. Hence it is necessary to understand the response of different parameters in the greenhouse on crop yield. After knowing that the choice of different crops to be grown in greenhouse can be fixed.

4.1 Plant response to greenhouse environment:

The productivity of a crop is influenced not only by its heredity but also by the micro-climate around it. The components of the crop micro-climate are light, temperature, air compositions and the nature of the root medium. In open fields, only manipulation of the nature of the root medium by tillage, irrigation and fertilizer applications is possible. Even in this case, the nature of the root medium is modified but not controlled. Whereas a greenhouse, due to its closed boundaries permits control of any one or more of the components of the micro-climate. These are as follows:

4.1.1 Light: The visible light of the solar radiation is a source of energy for plants. Light energy, carbon dioxide (CO₂) and water, all enter into the process of photosynthesis through which carbohydrates are formed. The production of carbohydrates from carbon dioxide and water in the presence of chlorophyll, using light energy is responsible for plant growth and reproduction. The rate of photosynthesis is governed by available fertilizer elements, water, carbon dioxide, light and temperature.

The photosynthesis reaction can be represented as follows,

Considerable energy is required to reduce the carbon that is combined with oxygen in CO₂ gas to the state in which it exists in the carbohydrate. The light energy thus utilized is trapped in the carbohydrate. If the light intensity is diminished, photosynthesis slows down and hence the growth.

If higher than optimal light intensities are provided, growth again sl_{0W_S} down because of the injury to the chloroplasts.

The light intensity is measured by the international unit known as lux. It is the direct illumination on a surrounding surface that is 1 metre from a uniform point source of 1 international candle. Greenhouse crops are subjected to light intensities varying from 129.6 klux on clear summer days to 3.2 klux on cloudy winter days. For most crops, neither condition is ideal, Many crops become light-saturated, in other words, photosynthesis does not increase at light intensities higher than 32.3 klux. Rose and carnation plants will grow well under full summer light intensities. In general, for most other crops foliage is deeper green if the greenhouse is shaded to the extent of about 40% from mid-spring (May) to midfall (Aug. and Sept). Thus, it is apparent that light intensity requirements of photosynthesis vary considerably from crop to crop.

Light is classified according to its wave length in nanometers (nm). Not all light is useful in the photosynthesis process. UV light is available in the short wavelength range i.e. less than 400 nm. Large of quantities of it is harmful to the plants. Glass screens are opaque to most UV light and light below the range of 325 nm. Visible and white light has wavelengths of 400 to 700 nm.

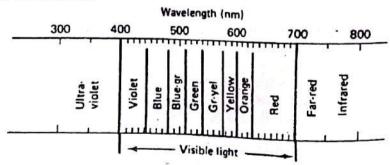


Fig 4.1 Spectrum of solar radiation

For red light (700 to 750 nm) affects plants, besides causing photosynthesis. Infrared rays of longer wavelengths are not involved in the plant process. It is primarily the visible spectrum of light that is used in photosynthesis. In the blue and red bands the photosynthesis activity is higher. When the blue light (shorter wavelengths) alone is supplied to

plants, the growth is retarded and the plant becomes hard and dark in color. When plants are grown under red light (longer wavelengths), growth is soft and internodes are long, resulting in tall plants. Visible light of all wavelengths is readily utilized in photosynthesis.

4.1.2 Temperature: Temperature is a measure of the level of heat present. All crops have a temperature range in which they can grow well. Below this range, the plant life processes stop due to ice formation within the tissue tying up water and cells are possibly punctured by ice crystals. At the upper extreme, enzymes become inactive and again process essential for life cease. Enzymes are biological reaction catalyst and are heat sensitive. All biochemical reactions in the plant are controlled by the enzymes. The rate of reaction controlled by the enzyme often doubles or triples for each rise of temperature by 10°C, until an optimum temperature is reached. Further increase in temperature begins to suppress the reaction and finally stop it.

As a general rule, greenhouse crops are grown at day temperature which is 3°C to 6°C higher than the light temperature on cloudy days and 8°C higher on clear days. With CO₂ enrichment, the day temperature may be higher by 3°C. The night temperature of greenhouse crops is generally in the range of 7°C to 21°C. Primula, mathiola incana and calceslaria grow best at 7°C, carnation and cineraria at 10°C, rose at 16°C, chrysanthemum and poinsettia at 17°C to 18°C and African violet at 21°C to 22°C.

4.1.3 Relative humidity: As the greenhouse is a closed space, the relative humidity of the greenhouse air will be more when compared to the ambient air, due to the moisture added by the evapotranspiration process. Some of this moisture is taken away by the air leaving from the greenhouse due to ventilation sensible heat inputs also lower the relative humidity of the air to some extent. In order to maintain desirable relative humidity levels in greenhouses, processes like humidification or dehumidification are carried out. For most crops, the acceptable range of relative humidity is between 50 to 80%. However, for plant propagation work relative humidity up to 90% may be desirable.

In summers, due to sensible heat condition in the day time and in winters for increasing the night time temperature of the greenhouse air, more sensible heat is added causing a reduction in the relative humidity of the air. For this purpose evaporative cooling pads and fogging systems

for humidification are employed. When the relative humidity is on the higher side, ventilators, chemical dehumidifiers and cooling coils are used for dehumidification.

4.1.4 Ventilation: A greenhouse is ventilated for either reducing the temperature of greenhouse air or for replenishing carbon dioxide supply or for moderating the relative humidity of the air. Air temperature above 35°C are generally not suited to crops in greenhouse. It is quite possible to bring greenhouse air temperature below this upper limit during spring and autumn seasons by simply providing adequate ventilation for the greenhouse. The ventilation in a greenhouse can either be natural or forced. In case of small greenhouse (less than 6 m wide) natural ventilation can be quite effective during spring and autumn seasons. However, fan ventilation is essential to have precise control over the air temperature, humidity and carbon dioxide levels.

4.1.5 Carbon dioxide: Carbon is an essential plant nutrient and is present in the plant in greater quantity than any other nutrient. About 40% of the dry matter of plants is composed of carbon. Under normal conditions, carbon dioxide (CO₂) exists as a gas in the atmosphere slightly above 0.03% or 345 ppm. During the day, when photosynthesis occurs under natural light, the plants in a greenhouse draw down the level of CO₂ to below 200 ppm. Under these circumstances, infiltration or ventilation increases CO₂ levels, when the outside air is brought in to maintain the CO₂ at ambient levels of CO₂ by providing ventilation may be uneconomical due to necessity of heating the incoming air in order to maintain proper growing temperatures. In such regions enrichment of the greenhouse with (CO₂) is followed. The exact (CO₂) level needed for a given crop will vary, since it must be correlated with other variables in greenhouse production such as light, temperature, nutrient levels, cultivate and degree of maturity. Most crops will respond favourably to CO₂ at 1000 to 1200 rpm.

4.2 Choice of crops for greenhouse cultivation:

The choice of crops grown in the greenhouse are mainly made on the basis of physical size of the structure and economic feasibility of particular type of crop. As a result high value horticultural crops have been more plant propagation material are another important commercial aspects of greenhouse technology.

Commonly grown greenhouse crops mentioned as follows:

Vegetables: Tomato, Cucumber, Lettuce, Onion, Cabbage, Beans, Peas, Spinach, Egg plant, Peppers, Squash, Chillies, Radish, Okra.

Fruits: Strawberries, Grapes, Citrus, Melons.

Ornamental crops: Roses, Poinsettias, Potted plants.

Other crops: Tobacco, Nurseries, Chrysanthemums plants.

Production management of some greenhouse crop is discussed below









i) Tomato (Lycopersicon escwentum Mill)

In India tomato has become a very important vegetable during last 60 years. The fruit can be seen in the market throughout the year. Although a ripe tomato contains as much as 93 to 94 per cent water, it has a high nutritive value being a good source of vitamin A and B and excellent source of vitamin C. It is very appetizing, removes constipation and has a pleasing and refreshing taste.

Climate: The tomato requires warm weather and plenty of sunshine for its best development. Prolonged cold, cloudy weather or repeated low temperature without actual freezing, check growth and may impair permanently the fruiting liabilities of the plants. Immature tomato blossoms drop rapidly during heat and drought as a result of increased transpiration. During warm and sunny weather, the fruit ripens best for yield, color and quality seed and sowing. Being a self pollinated crop seed raising in tomato is comparatively simple and seed raised from a healthy plant will normally breed true to type even different varieties of tomatoes are grown in adjoining plots.

Tomato seeds of outstanding performance in respect to genetic factor and freedom from disease should be procured for sowing. As 400 to 425 gm of seed will produce sufficient plants for one hectare under open field conditions, where as this amount will be less for pot or field cultivation

under greenhouse system of production.

Soil and its preparation: Tomato is grown on a variety of soils from sandy loam to heavy clay. However, for obtaining high yields, a well drained heavy loam is the best. In general, tomato succeeds well on loams silt loams and clay loams. The soil should be well ploughed up and well manured before the seedlings are transplanted. Usually, 20 to 25 tonnes of well rotten farm yard manure (FYM) is applied per hectare for field condition and bit higher for pot cultivation as it is to be mixed with heavy loams before filling into the pots. In addition, about 110 to 120 kg. of phosphorous in the form of super phosphate is also beneficial. If too much nitrogenous fertilizer is applied, there will be luxuriant growth of foliage and less of fruiting. The tomato responds to liberal fertilization at planting time and bear picking time. About 300 to 335 kg. per hectare of ammonium sulphate should be applied as a top dressing, for field condition and less for pot, in three split doses around the plants, taking care that the fertilizer does not touch the plant parts. The first dose of about 100 to 115 kg. to be applied when the plants have set after transplanting, the second dose of equal quantity in the second month and third dose after the fruit set.

Planting: Tomato is first sown in seedbed or in pot and the seedling are later transplanted in either field or in pot when they are about 12 to 15 cm. in height. In case of field condition, the spacing of 75 cm \times 60 cm is taken. As pots behave as independent, distance management can be done accordingly keeping in view that each plant get sufficient sunlight required for photosynthesis.

Irrigation and weed control: Generally, under open field condition, irrigation is not essential for tomato production in humid region but in case of greenhouse, irrigation is required to create that humidity. This could be achieved by either irrigating the crop as and when required or maintaining the desired humidity through misting. Tomato withstands drought fairly well but irrigation is given at long intervals radial or concentric cracks may develop on the fruit.

Clean tillage is essential for high yields. Hand hoeing is always helpful to keep down the weed growth. Yields are depressed following the growth of many weeds to a height of few centimeters.

Harvesting: The utmost care should be taken in preparation of harvest if highest prices are to be realized. The stage of harvesting depends upon

the distance of market and time to be taken in marketing the produce. Tomatoes for local market should be picked when fully ripe and for distant markets when they are turning pink. For far off and distant market they may be harvested even earlier i.e. when they are in turning green stage. Any stems should be removed and tomatoes should be cleaned.

Climatic conditions which prevail during the winter affect number of quality parameter in tomatoes. Puttiness of tomato fruits can be controlled by heating of the greenhouse. Blotchy ripening can be eliminated by heating the air. On the other hand soil heating increases the blotchy fruit incidence.

ii) Cucumber (Cucumis Sativus L.)

Locally known as kheera, the cucumber is a very popular and widely cultivated vegetable in both open fields as well as in greenhouse during off season. The crop is very popular in many European countries also and produced mainly for shipment and pickling. In India, it is eaten raw with salt and pepper or as salad with onion and tomato. The fruit is said to have a cooling effect and prevents constipation and said to be useful in checking jaundice. The fruit contains vitamins B and C.

Climate: A warm season crop which is highly susceptible to frost. Temperature ranging from 26 to 30°C is most favourable and could be easily achieved inside greenhouse during winter. It also requires protection against strong wind which is not possible in open field condition.

Soil: For early crop, sandy or sandy loam is desirable but where heavy yields are the criterion, silt and clay loams are preferred being their capacity to retain moisture for longer duration. The land should be ploughed two or three times to prepare the field adequately.

Manuring: A basal dose of 35 to 45 tonnes of farm yard manure (FYM) per hectare should be worked into the soil before sowing. Inorganic fertilizers at the rate of 50 kg ammonium sulphate, 100 kg. super phosphate and 55 kg potassium sulphate per hectare may be applied at the time of final field preparation. In addition to this, ammonium sulphate may also be applied as a top dressing at a rate of 40 to 60 kg per hectare in two separate doses – first when the plant starts to run and later when fruiting has started.

Sowing: Sowing for off-season crop or for spring summer crop may be made early in December for preparation of seedlings. When the height of plants becomes 10 to 15 cm (3 to 4 weeks), they are transplanted in the

already prepared field or in pot as per the availability of space and soil conditions. About 2.5 kg of seed per hectare is sufficient. The seed require a temperature well above 10°C and up to 30°C for good germination.

Pollination: Although cucumber is self pollinated but in closed structure like greenhouse where pollination agents like wind, insects etc. are not feasible, manual pollination is done. The time of the pollination should be between 8 am to 10 am for getting optimum yield.

Cultural Practices: During dry weather, at least weekly irrigation may be required, when inside temperature shoots up above 30°C. Two or three weeding may be required and these operations should be shallow since the plants have a shallow root system.

Harvesting: The crop may become ready for harvest in 60 to 75 days after sowing. The season extends over a period of two months. Picking may be necessary every second or third day. The fruits are picked by cutting or breaking the stem close to the fruit. Allowing fruits to mature is reported to retard growth of new fruits and yield, so harvesting at right stage is necessary.

iii) Chilli (Capsicum annum. L.)

The capsicum is believed to have originated in the tropical America. They were important food plants in early times and now are popular the world over. The small fruited kinds are hot and pungent and the large fruited once are generally mild. The later form chiefly the vegetable and one cooked as stuffed with many food preparations.

Climate: The crop is tender to frost but does not require high temperature.

Soil: A warm deep fairly moist and fertile sandy loam is preferable. The drainage must be good. The soils with high moisture rention capacity are chosen where the crop is grown as unirrigated crop.

Seeds and sowing: Like tomoto, the chilli seedlings are first started in nursery and later transplanted. The sowing is done from June to September in the plains and from March to May in the hills under open field condition. Whereas in case of greenhouse cultivation, sowing can be done from December to March. A high temperature is said to promote early and good germination. Seed beds are well prepared and seeds are sown in rows about 4 cm apart. The seeds germinate in about two weeks. When the

plants are about 100 cm high, they are ready for transplanting. Preparation of field is similar to that of tomato. For field conditions spacing of 60 to 75 cm x 30 to 45 cm is recommended. The seed requirement per hectare is about 1.25 to 1.50 kg.

Manuring, irrigation and weeding etc. are similar to that of tomato.

Harvesting: The fruits of vegetable type of capsicum are picked as soon as they attain marketable size. The fruit starts ripening about three months after transplanting and picking may go on for two or three months. They are sold mostly green. The fruits should be snapped or twisted off from the stem. Chillies are harvested mature green for salad, vegetable and pickle and for condiments when they are fully ripened and turned red.

iv) Pepper

Pepper fruit malformation is caused by low temperatures prevailing during early stages of flower development. Under such conditions, there is an excessive enlargement and deformation of the ovary resulting in production of deformed fruits. In addition, ovary enlargement is associated with the production of many parthenocarpic fruits due to improper fertilization, although pollen may be abundant and viable. Low temperature causes concentrated pepper fruit set which results in great abundance of fruits on short, internodes. This morphological development may itself be an important factor which enhances fruit malformation.

EXERCISES

- 1. How temperature changes affect the plant growth processes?
- Describe different micro-climatic parameters affecting the growth of crop in controlled environment.
- Write short notes on
 - Relative humidity
 - Greenhouse ventilation b)
 - Carbon dioxide levels in greenhouse
- What are the different crops which can be grown in controlled environment?
- Write in brief about cultivation of tomato in greenhouse.





SYSTEMS IN GREENHOUSE

A need to cool a greenhouse arises whenever the greenhouse air temperature exceeds the upper limit of the crop tolerance. Failure to bring down the temperature effectively may result in either partial or total crop failure within only a very short period of time. Consideration for appropriate cooling systems is essential because temperatures are on higher side for long period in most of the parts of India. Process of cooling system includes selection of cooling method and its designing. Ventilation is the process of allowing the fresh air to enter into the enclosed area by drawing out the air with undesirable properties. In greenhouse context, ventilation is essential for reducing temp. replenishing CO, and controlling RH. Ventilation requirements of GH vary greatly depending upon the crop grown and the season of production, selection of relevant components of equipments and provision of controls.

5.1 Methods of greenhouse cooling:

Several methods based on convection / forced air movement with/ without the evaporation of water are available for cooling of greenhouses. They are explained below.

5.1.1 Ventilation:

Ventilation is the process of allowing the fresh air to enter into the enclosed area by driving out the air with undesirable properties. In greenhouse context, ventilation is essential for reducing temperature, replenishing CO, and controlling relative humidity.

Ventilation requirements for greenhouse vary greatly depending upon the crop grown and the season of the production.

5.1.1.1 Ventilation with roof and side ventilators:

The top ventilators are provided in the roof and rollable curtain arrangement is made by the four sides. The hot air from greenhouse is removed from top ventilators and it is replaced by ambient air from sides. Top ventilators are having the depth of 0.6 to 1.0 m, whereas side curtain has the width of 1.5 to 3.0 m depending upon the column height.

The ventilation area should be at least 20% of floor area for effective ventilation.

Generally, such type of structure is affected structure. The air movement in such structure is affected by temperature difference between inside and outside. The wind has also considerable effect on air movement. The cooling system of naturally ventilated structure can not be designed precisely because temperature difference and wind (velocity & direction) are highly variable. The correct placement of top ventilators and proper greenhouse orientation will have partial control over temperature inside greenhouse.

5.1.1.2 Roof shading:

Partial shading is used to reduce the intensity of sunlight in the cropped area. Shading can be done by two methods.

- Application of white wash: Application of white wash with any white material like distemper or lime over glazing material is comparatively and less expensive method. Such a paint washes off by itself by the rain.
- Shading screen: It can be used for a part of growing season or if a specific level of shade is required. The material may be Poly Propelene (PP), Poly Ethylene (PE) or Polyster with different grades of shade like 20%, 25%, 35%, 50%, 75% and 90%.

5.1.2 Evaporative cooling: (EC)

The degree of cooling obtained from an evaporative system is directly related to the dry-wet bulb difference that occurs with a given set of climatic condition. Evaporative cooling systems are most effective in areas where a consistently low relative humidity exists. Generally, the period of lowest humidity occurs during the hottest part of the day when the greatest degree of cooling is required and evaporative cooling is more effective. The relative humidity increases as night temperature declines and little or on cooling is required.

5.1.2.1 Fan and pad system:

It is adaptable to both large and small greenhouses. In this system, low

velocity and large volume fans draw air through wet fibrous pads mounted on the opposite side or end wall of the greenhouse. The outside air is cooled to 3-12°C depending upon sunlight intensity, relative humidity and the amount of shading compound applied.

The pad can be made of different materials viz. gravel, straw, wood fiber, khus, honey comb paper & charcoal. Most of the greenhouse will require about 1 m of pad height for every 20 m of pad to fan distance. Pad design should provide at least 6 lit water/min per running meter of the nad system of 1 m height. Due to continuous watering, pads accumulate salts sag and thus create openings that allow hot air to enter the greenhouse The efficient pad material is of honey comb cellulose paper but it is very costly.

Placement of exhaust fans also affects the distribution of cooled air. They should not be located more than 9 m part otherwise warm areas will develop. Fans should be placed on the side against the direction of prevailing winds. Thermostatistically operated fan and pad system is desirable for uniform and automatic control of temperature. Humidstate may be installed to avoid excess humidity.

5.1.2.2 High pressure mist system :

Water is sprayed into the air above the plants at pressure of 35-70 kg/cm 2 from low capacity nozzles (1.9 to 2.8 lph). A fine mist fills the greenhouse atmosphere cooling the air as it evaporates. Although most of the mist evaporates before reaching the plant level, some of the water settles on the foliage where it reduces leaf temperature. Temperature difference of 5-14°C can be obtained between high pressure mist & fan cooled greenhouses. It is more effective during the warmest part of the day.

5.1.2.3 Low pressure mist system:

Misting with water pressure less than 7kg/cm² have achieved air temperature 5°C cooler in a greenhouse compared to natural ventilation. The water droplets from a low pressure misting system are quite large and do not evaporate quickly. Leaching of nutrients from soil is a serious

5.2 Greenhouse irrigation systems:

A well-designed irrigation system will supply the precise amount of A well-designed in gasterness amount of water needed each day throughout the year. The quantity of water needed

would depend on the growing area, the crop, weather conditions, the time of year and whether the heating or ventilation system is operating. Water needed is also dependent on the type of soil or soil mix and the size and type of the container or bed. Watering in the greenhouse most frequently accounts for loss in crop quality. Though the operation appears to be the simple, proper decision should be taken on how, when and what quantity to be given to the plants after continuous inspection and assessment. Since underwatering (less frequent) and overwatering (more frequent) will be injurious to the crops, the rules of watering should be strictly adhered to.

5.2.1 Rules of watering:

The following are the three important rules of application of irrigation water.

Use a well-drained substrate with good structure. Rule 1.

If the root substrate is not well drained and aerated, proper watering cannot be achieved. Hence substrates with ample moisture retention alongwith good aeration is indispensible for proper growth of plants. The desired combination of coarse texture and highly stable structure can be obtained from the formulated substrates and not from field soil alone.

Water thoroughly each time. Rule 2.

Partial watering of the substrates should be avoided; the supplied water should flow from the bottom in case of containers and the root zone is wetted thoroughly in case of beds. As a rule, 10 to 15% excess of water is supplied. In general, the water requirements for soil based substrates is at a rate of 20 1/m2 of bench, 0.3 to 0.35 litres per 16.5 cm diameter pot.

Water just before initial moisture stress occurs. Rule 3.

Since overwatering reduces the operation and root development, water should be applied just before the plant enters the early symptoms of water stress. The foliar symptoms, such as texture, colour and turgidity can be used to determine the moisture stresses but they vary with crops. For crops that do not show any symptoms, colour, feel and weight of the substrates are used for assessment.

Different irrigation water application systems are discussed as follows:

5.2.2 Hand watering:

The most traditional method of irrigation is watering and in present days is uneconomical. Growers can afford hand watering only where a crop is still at a high density, such as in seed beds or when they are watered at a few selected pots or areas that have dried sooner than others. In all cases, the labour saved will pay for the automatic system in less than one year. It soon will become apparent that this cost is too high. In addition to this deterrent to hand watering, there is a great risk of applying too little water or of waiting too long between watering. Hand watering requires considerable time and is very boring. It is usually performed by inexperienced employees, who may be tempted to speed up the job or put it off to another time. Automatic watering is rapid and easy and is performed by the grower himself. Where hand watering is practiced, a water breaker should be used on the end of the hose. Such a device breaks the force of the water, permitting a higher flow rate without washing the root substrate out of the bench or pot. It also lessens the risk of disrupting the structure of the substrate surface.

5.2.3 Perimeter watering:

Perimeter watering system can be used for crop production in benches or beds. A typical system consists of a plastic pipe around the perimeter of a bench with nozzles that spray water over the substrate surface below the foliage as shown in Fig.5.1.

In this system either polyethylene or PVC pipe can be used. While PVC pipe has the advantage of being very stationary, polyethylene pipe tends to roll if it is not anchored firmly to the side of the bench. This causes nozzles to rise or fall from proper orientation to the substrate surface. Nozzles are made of nylon or a hard plastic and are available to put out a spray arc of 180°, 90° or 45°. Regardless of the types of nozzles used, they are staggered across the benches so that each nozzle projects out between two other nozzles on the opposite side.

Perimeter watering system with 180° nozzles require one water valve for benches up to 30.5 m in length. For benches over 30.5 m and up to 61.0m, a water main should be installed on either side, one to serve each half of the bench. This system applies 1.25 1/min/m of pipe. Where 180°, 90°, or 45° nozzles are alternated, the length of a bench serviced by one water valve should not exceed 23 m.

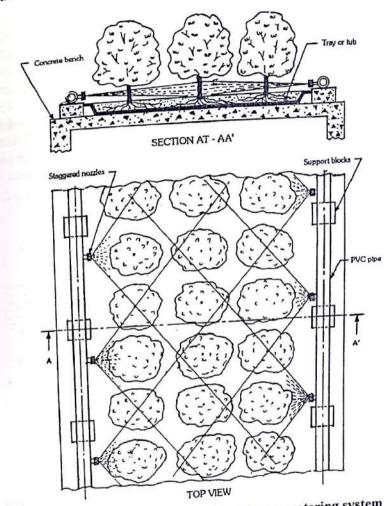


Fig. 5.1 Schematic diagram of perimeter watering system

5.2.4 Overhead sprinklers:

While the foliage on the majority of crops should be kept dry for disease control purposes, a few crops do tolerate wet foliage. These few crops can most easily and cheaply be irrigated from overhead. Bedding plants, azelea liners and some green plants are crops commonly watered from overhead as shown in Fig.5.7. A pipe is installed along the middle of a bed. Riser pipes are installed periodically to a height well above the final height of the crop. A total height of 0.6 m is sufficient for bedding plants flat and 1.8 m for fresh flowers. A nozzle is installed at the top of each riser. Nozzles vary from those that throw a 360° pattern continuously to types that rotate around a 360° circle. Trays are sometimes placed under pots to collect water that would otherwise fall on the ground between pots and is wasted. Each tray is square and meets the adjacent tray. In this way nearly all water is intercepted. Each tray has a depression to accommodate the pot and is then angled upward from the pot toward the tray perimeter. The trays also have drain holes, which allow drainage of excess water and store certain quantity, which is subsequently absorbed by the substrate.

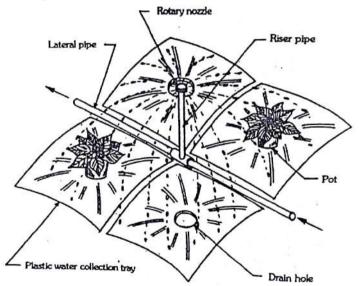


Fig. 5.2 Schematic diagram of overhead sprinkler watering system.

5.2.5 Boom watering:

Boom watering can function either as open or a closed system and is used often for the production of seedlings grown in plug trays. Plug trays are plastic trays that have width and length dimensions of approximately 30 cm × 1 cm, a depth of 1.3 cm to 3.8 cm and contain about 100 to 800 cells. Each seedling grows in its own individual cell. Precision of watering is extremely important during the 2 to 8 week production time

of plug seedlings. A boom watering system generally consists of a water pipe boom that extends from one side of a greenhouse bay to the other. The pipe is fitted with nozzles that can spray either water or fertilizer solution down onto the crop. The boom is attached at its center point to a carriage that ridges along rails, often suspended above the center walk of the greenhouse bay. In this way, the boom can pass from one end of the bay to the other. The boom is propelled by and electrical motor. The quantity of water delivered per unit area of plants is adjusted by the speed at which the boom travels.

5.2.6 Drip Irrigation System:

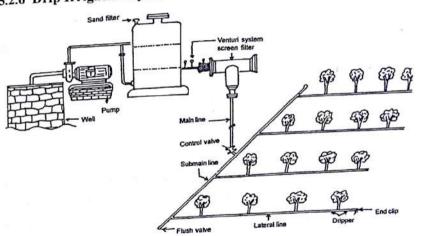


Fig. 5.3 Different components of drip irrigation system.

Drip irrigation is the application of small amount of water near the root zone of the plants at frequent intervals through emitting devices via a network of PVC mainline, submain, filtration unit, control valves, laterals and drippers.

This system applies water slowly, almost matching with the consumptive water use by the plant, to keep the soil moisture within the desired range of available moisture to plant growth. Water is discharged drop by drop at very low rate of a few liters per hour. This system minimizes the water losses in the conventional irrigation methods such as deep percolation, runoff and evaporation.

Drip irrigation is one of the latest method of irrigation, which is becoming increasingly popular in areas with water scarcity and salt problem Drip irrigation is the best means of water conservation. In general, the application efficiency is 90 to 95%, compared with sprinkler at 70% and furrow irrigation at 30 to 50 %. Drip irrigation is not only recommended for protected agriculture but also for open field crop production, especially in arid and semi-arid regions of the World. Drip irrigation is also known as trickle irrigation.

5.2.6.1 Benefits of Drip Irrigation

- Water saving to the tune of 30 to 70 per cent.
- Increased plant vigor and crop yield.
- Labor saving.
- Use of pure quality water is possible. It reduces the salt concentration in the root zone when irrigated with poor quality ground water.
- No interference with cultural practices.
- Can be used in hilly regions and on saline or alkali soils.
- vii. Reduced weed growth due to partial wetting of the soil.
- iix. Saving in fertilizer.
- Less disease and pest problem.
- Irrigation application rate can be adjusted as per the soil type.
- Water and fertilizer can be applied uniformly to each plant.
- xii. Integration with other agro-technical activities is possible. In intensive agriculture it is important to irrigate, spray, weed control, cultivate and harvest at the optimum time.
- xiii. Fun to do: Drip irrigation systems are fun. They are user-friendly and plant-friendly. They will add to your life by simplifying it. Setting up a system is fun and only requires a few hours. Kids love to help,

5.2.6.2 Component of Drip System:

A drip irrigation system consists of filters, mainline, submains, laterials, drippers (emitters), and other small fittings and accessories such as valves, pressure regulators, pressure gauge, fertilizer application components etc.

1. Filter: A filter unit removes the suspended impurities in the irrigation

water, so as to prevent blockage of holes and passage of drip nozzles. The type of filtration needed depends on water quality and emitter type. A two-stage filter unit is usually used.

Gravel filter (Sand filter): These filters are effective against both inorganic and organic suspended solids. This type of filter is essential for using water from open reservoir in drip irrigation. The dirt and algae is stopped and accumulated inside the media in the filter unit. Gravel filter consists of small basalt gravel or sand (usually 0.7 to 2 mm diameter) placed in a metallic cylindrical tank. Water with suspended impurities enters from the top, flows through the filter bed and clean water comes out at the bottom, leaving the dirt in the filter. The filter is cleaned by reversing the direction of flow from time to time. Pressure gauges are fitted at the inlet and outlet of the filter. When the dirt accumulates, the pressure difference is more than 0.5 to 1.0 kg/cm² (5 to 10 m of water), and then filters must be cleaned by opening the cover or back washing. Automatic self-cleaning filters are also available.

The flow rate of the filters may be 10 to 50 m³/hr and the tank diameter may range from 10 to 50 cm depending on the capacity of

- Screen filter: A screen filter is often placed down stream to the sand filter and this may be installed with or without gravel filter, depending upon quality of water. The screens are usually cylindrical in shape and are made up of non-corrosive metal or plastic material. Screen filters are specified as below:
- By the diameter of inlet and outlet (ranges from 25 mm to 110 mm).
- By the recommended range of flow rate (ranges from 3, 5, 7, 10, 15,
- By the size of holes in the screen in mm, micron or in term of mesh that is the number of holes per square inch. As an approximation 20, 40, 80, 100, 120, 150 and 200 mesh. The most common mesh 20, 40, 60, 100, selected for drip irrigation is 100 to 200 mesh (0.15 mm to 0.08 mm
- By the total surface area of the filter (cm²) or the active or net filter area, which is usually about 1/3rd of the total filter surface area.

- By the cleaning methods: Manual or automatic. The head loss across the filter should not be more than 3 m and otherwise needs cleaning. The filters are cleaned by flushing the screen with a stream of water. After cleaning, the screen is checked for tears and the gasket should be checked and replaced when necessary.
- With relatively clean water, only screen filters may be used.
- c) Disc filter: The filtration element is made up of grooved plastic discs, which are piled together around a telescopic core, according to the desired degree of filtration. Both sides of the discs are grooved and the grooves cross each other, when piled up and tightened together. The housing is made up of plastic or metal and comes in many different sizes mainly 25 mm to 90 mm. The water passes through the filter from the outside to the inside. There is no danger of filter tearing. The filtration is effective in two stages. The larger outer surface operates as a screen filter and collects the larger particles. The grooves inside the disc allow the adhesion of fine particles, mainly organic matter. The filter element can be cleaned easily by opening the core. The discs are released and can easily be rinsed under running water. The pressure drop is slightly higher than screen filter but disc filters have tangent to the discs to allow them in spin freely.
- 2. Main Line: The mainline conveys the water from filtration system to the submain. They are normally made of rigid PVC and HDPE pipe 60 to 90 cm below the ground, so as not to interfere with cultivation practices. Their diameter is based on the system flow capacity. The frictional head loss should be less than 5m per 1000 m running length
- 3. Submain: The submain conveys the water from mainline to the laterals. They are also buried in ground below 45 cm to 60 cm and than main line, for economy. There may be number of submains from one main line depending upon the plot size and crop type.
- 4. Laterals: Laterals are small diameter flexible pipes or tubings made of linear low density polyethylene (LLDPE) and having 12mm, 16

mm and 20 mm diameter. These are coloured black to avoid algae growth inside and minimize the damaging effect of ultra-violet radiation. They can withstand maximum pressure of 4 kg/cm². They are connected to submain at predetermined distance. The pressure variation between two extreme points of a lateral should not be more than 15 to 20 per cent and discharge variation should not be more than 10 per cent. On slopping ground, the lateral are placed along the contour with 1 per cent extra length.

5. Emitters or drippers :

They discharge water from lateral on to the soil near the plants. There are various types and sizes of drippers, based on different operating principles. They are made of plastic such as polyethylene or polypropylene. Their discharge ranges between 1 to 15 lit/hr. Each dripper has its own characteristics, advantages and limitations, which determines its use.

The drippers can be classified according to working principle, discharge, type, structure, working pressure, durability, pressure compensating and non pressure compensating principle. The main principle in dripper selection is to achieve the minimum discharge with maximum size of water passage The large water passage is essential to minimize clogging and provide the minimum discharge for cheapest set-up. Therefore, an emitter is necessary (a hole in a pipe is not a dripper). Emitters may be punched externally on the lateral or may be fitted in the lateral. Accordingly they are called as online or inline emitters, respectively.

- 6. Control valves (Ball valves): These are used to control the flow through the submain pipes. Generally, they are installed on filtration system, mainline and on all submains. They are made up of gun metal, PVC, cast iron and their size ranges from 20 mm to more than
- Flush valve: It is provided at the end of each submain to flush out the water and dirt accumulated at the end of submian.
- 8. Air release cum vacuum breakage valve: It is provided at the highest point in the main line to release the entrapped air during the start of system and to break the vacuum during shut off. It is also provided on submain if submain length is more.

- Non-return valve: It is used to prevent the damage of pump from back flow of water hammer in rising main line of drip irrigation system.
- 10. Pressure Gauge: It is used to indicate the operating pressure of the drip system. The pressure gauges are installed at the inlet and outlet of the sand and screen filters.
- 11. Grommet and take-off: These are used to connect the lateral to submain. A hole is punched with hand drill of predetermined size in submain. Grommet is fixed into the hole on submain. Take off is pressed into the grommet with take of punch up to the step provided. Grommet acts as a seal. The sizes are different for 12 mm, 16 mm and 20 mm lateral diameter.
- 12. End caps (End sets): They are used to close the lateral ends, submain ends or mainline ends. Submains and mains are preferably provided with flush valve. They are convenient for flushing the line.
- 13. Fertilizer system: It is used to add the chemicals (nutrients, herbicides, pesticides etc.) to the irrigation water. However, fertigation is not free of hazard. Chemicals added to the water may be toxic to the human beings and animals. Therefore, care must be taken to prevent the back flow of irrigation water into the source, which might be used for drinking purpose.

EXERCIES

- O.1. What are the rules of watering?
- Q.2. Enlist different irrigation water application systems and describe the perimeter watering system in brief.
- Q.3. Enlist the different components of drip irrigation system.
- Q.4. Describe the ventilation method of greenhouse cooling.
- Q.5. What is evaporative cooling?





DRYING

6.1 Introduction:

Drying of agricultural products is an important unit operation under post harvest phase. It refers to the removal of moisture from grains and other products to a predetermined level, whereas dehydration means removal of moisture to very low levels usually to bone drying condition. Drying is a thermo-physical and physico-chemical operation by which the excess moisture from a product is removed. Drying makes the food grain and other products suitable for safe storage and protects them against attack of insects, molds and other micro-organisms during storage. It has been found by several experiments that harvesting of crops at higher moisture content and subsequent drying to safe moisture levels leads towards saving of grains to the tune of 6 to 7 per cent. For example, if paddy is harvested at 20% to 22% moisture content and later on dried to 14% moisture content, it has a potential of increasing rice yield by 10% in comparison to harvesting paddy at 14% moisture content. Therefore, it is important to do the timely drying of agricultural products.

6.2 Drying process:

During drying the moisture from solid gets vaporized and diffused in the environment. Removal of moisture takes place by high pressure or high temperature conditions. Drying removes the volatile material present inside solid matters. In some products, drying is carried to bring down the moisture content to a predetermined limit.

Some amount of moisture present in the pore spaces of grains. Excess amount of moisture remains in bound form with absorbing materials of the grain. Mutual reaction takes place between absorbing materials and moisture molecules, finally the moisture chemically bounds with the chemical constituents of the food grains. Removal of moisture from wet materials by vaporization depends on the rate of heat and mass transfer, which is related with the following two basic phenomenons:

- Vaporization of moisture from surface of material.
- Movement of moisture from internal parts of material to its surface. The movement of moisture takes place because of diffusion cell contraction and vapor pressure gradient.

In Fig 6.1 the phenomenon of moisture removal from food grains in heated air drying is shown.

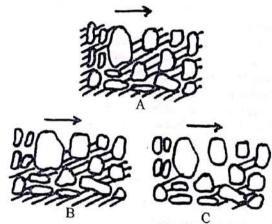


Fig. 6.1 Removal of moisture from capillaries of grains - Heated air flow. A: Distribution of moisture in crystalline solids in first stage. B: Distribution of moisture in solids in middle. C: Distribution of moisture in solids at the end of drying.

6.3 Advantages of drying:

Drying is thermo-physical and physico-chemical action and its dynamics principles are governed by heat and mass transfer laws inside and outside of the products. Drying is the most effective unit operation for protection of food grains and safe storage of agricultural products. Proper drying makes the material stable and thermal attack of insects and microorganisms during storage period can be kept at negligible level.

Different advantages of drying are as follows:

Drying permits early harvest of crops. This leads to reduction of

- losses by shattering. This also leads to permit time for preparation of land for sowing of next crops.
- Drying helps in proper planning of harvesting season. If adequate drying facilities are available then crop can be harvested as per the availability of labourers.
- Drying of agricultural products to optimum moisture content result in safe storage of products over a longer period. Grains are stored in large quantities for long period in government ware houses and industries for the subsequent use as and when required.
- Storage of products after drying makes products available during off seasons. Selling of grains in off season would fetch additional income to growers as prices remain higher during these periods.
- When grains are stored, due to increase in the temperature and moisture content, heat of respiration also increases. The heat of respiration can be removed by aeration and drying. Thus the temperature and moisture content of the products can be brought down and the viability of seeds could be maintained.
- Some agricultural by-products and waste products can also be converted into useful products by proper drying.

6.4 Grain drying (drying theory):

Drying is a convection process in which moisture from a product is removed. Dehydration is a process in which products are dried to very low moisture levels. It is necessary to understand the nature of air and composition of products to know the drying process.

The atmospheric air surrounding the grains is a mixture of different gases. It contains mainly oxygen 20.95%, nitrogen 78.09%, carbon dioxide 0.03% and argon 0.93%. Air also contains water-vapor. Water vapor creates pressure which is dependent on the amount present in air.

The composition of food grain is mainly dry matter i.e. starch and moisture. The water content of agricultural products is given in terms of moisture content. At the time of harvesting moisture content of products is high. By nature, food grains are hygroscopic. They gain or loss moisture as per the atmospheric conditions. The moisture migration into or from a product is dependent on the difference of vapor pressure between atmosphere and product. If the vapor pressure of grain is greater than atmospheric vapour pressure, transfer of moisture from grain to atmosphere takes place. But when the atmospheric vapors pressure is greater than grain vapors pressure, grain absorbs moisture from atmosphere.

Moisture remains inside any hygroscopic product in two forms,

- Bound moisture: In bound moisture, the water vapor pressure of grain is lower than the vapor pressure of free water surface. The highest bound moisture content is reached when the hygroscopic product is kept under 100% relative humidity condition.
- The unbound moisture: The unbound moisture content is more than the bound moisture content.

6.5 Methods/ Types of drying:

There are many methods for developing water vapor pressure difference between products and atmosphere. For drying of any product, the water vapor pressure of product can be increased or the air water-vapor pressure is decreased or both can be achieved simultaneously. For increasing the water vapor pressure of grains, the methods mostly followed are:

- Sun or solar drying
- Conduction drying
- Infra- red drying

The methods usually employed to lower the water vapor pressure of air are:

- Heated air drying 1.
- Desiccated air drying 2.
- 3. Refrigerated air drying

The agricultural product drying methods can be broadly grouped into two:

- Sun/Solar drying
- Artificial drying with mechanical means

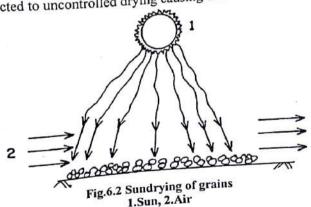
6.5.1 Sun drying:

This is a traditional method of drying of crops and grains and probably being followed by farmers since man has developed art of cultivation. Still, in India, major portion of crops is left in the field and threshing yard for

Methods of sun drying:

These methods are classified as follows:

- Drying of standing crops: Grains are dried on the plant till proper moisture content is attained. Then, the crop is harvested and threshed. But considerable quality is lost due to shattering. This drying process is slow and takes about 2 to 3 weeks after the grains have attained biological maturity.
- Drying of grain on stalk: This is an improvement over the previous method. The crop is harvested at higher moisture content and is left in the field or on bunds of the field till it has dried to proper moisture content. Another improved method is to dry the harvested crop on racks. Crop is bundled near the ears and hung on a rope exposing to
- Drying of threshed grains: The harvested crops at higher moisture content are threshed and the grains are spread on the floor in 1 to 3cm thick layer (Fig. 6.2). It is continuous stirred manually till it has attained the desirable moisture content. In this process, the grains are subjected to uncontrolled drying causing cracks in the kernels



It is the process of utilizing mechanical means to drying of grains 6.5.2 Mechanical drying: by vibrating natural or heated air through the grain mass to accomplish removal of moisture from it. The mechanical drying system is having following features.

- Rate of drying of grains can be controlled by controlling the temperature of hot air ventilation through grain mass.
- Grains can be dried in all seasons and also during night.
- iii. The process is automatic and requires a small number of unskilled labourers, however a trained person is required to operate the dryer.
- iv. Losses due to insects, birds and rodents are avoided.
- The process requires fuel or electrical or mechanical power to drive the air and their accessories. Cost of drying per unit mass is comparatively higher than sundrying.
- vi. The process requires little space for operation and is suitable for big mills.
- vii. Mechanical drying in conjunction with early harvest improves the milling quality of grains.

Mechanical drying methods:

Though moisture can be removed from products even by filtration or by pressing but the drying process commonly means removal of moisture due to simultaneous heat and mass transfer processes. The water-vapor from wet material is carried by a medium usually drying air. There are a number of products with varying physical and chemical properties can be dried by heated air. Methods of transfer of heat to products are also numerous. Hence, some of the basic and commonly used drying methods

6.5.2.1 Contact (Drum) drying:

In this method of drying, heat is supplied to wet products by conduction. For heat transfer, a heated surface like plate, cylinder, dryer wall is used as shown in Fig.6.3. The rate of heat transfer is dependent upon the thermal conductivity of the heated surface and also depends on the heat transfer coefficient from the heating medium to the surface. The commonly used heating medium in conduction drying commonly used are steam, organic liquids, metals and other materials with high values of heat transfer coefficients. Since all the heat which passes through the material is utilized for moisture evaporation, thermal efficiency of contact drying

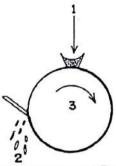


Fig. 6.3 Contact drying 1. Wet material, 2. Dry material, 3. Hot cylinder.

6.5.2.2 Convective drying:

In this method the sensible heat of heated air is transferred to the wet products by convection. Heat gaseous medium (usually air) is ventilated through a mass of wet material and carries with it the water-vapor evaporated from the material.

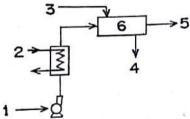


Fig.6.4 Convective drying 1. Ambient air, 2. Heater, 3. Wet material, 4. Dry material, 5. Exit air, 6.Drying chamber.

To save energy, sometimes the exit air from dryer is recirculated. Sometimes, the partially dried material is recirculated for further drying. In such situation the system is known as recirculatory dryer.

6.5.2.3 Freeze drying:

This method of drying is based on the sublimation of frozen moisture from the wet product placed in a drying chamber. The pressure in the drying chamber is low. Heat is supplied by radiation or conduction from heated trays and the temperature of product is not raised above 0°C. The sublimated moisture is condensed on refrigerated plates in the drying chamber but these plates do not come in contact with products.

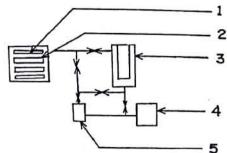


Fig.6.5 Freeze dryers schematic diagram 1.Dry material, 2.Heating surface, 3.Condencser, 4.Vacuum pumps, 5.Diffusion pump.

6.5.2.4 Radiation drying:

Heat energy can be supplied to wet products by electro-magnetic waves. The wave length of the electro-magnetic radiation lies between 0.76 to 400 um. The radiation within this wave length is also called infra-red radiation. The infra-red penetrates the surface of wet material and causes vibrations of molecules, which creates thermal effect. Since the penetration depth of infra-red waves is relatively small, this method of drying is commonly used for drying of thin materials. The moisture migration inside the material and diffusion of vapour follows the same laws as in convective or contact

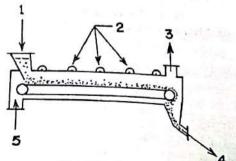


Fig.6.6 Radiation dryer 1. Wet material, 2. Radiator, 3. Exit air, 4. Dry material, 5. Air inlet.

6.5.2.5. Super heated steam drying:

In this method of drying as shown in Fig. 6.7, first of all the dryer is filled with hot air and normal convection drying takes place. The water vapor evaporated during drying operation starts to circulate with hot-air. Over pressure is released by a pressure control valve and the air is gradually replaced by water vapor. At the end of drying, water vapor with a small amount of air is circulated.

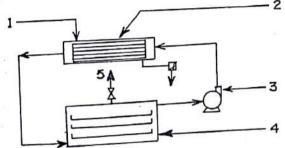


Fig.6.7 Super heated steam dryer 1.Steam inlet, 2.Gas heater, 3.Blower, 4.Dryer, 5.Exit.

6.5.2.6. Osmotic drying:

This method of drying can be successfully applied for dewatering of cellular products such as fruits, vegetables, meat etc. For the moisture removal, osmo-active substances like 60% aqueous solution of sacc harose or 25% aqueous solution of sodium chloride is used. The difference in osmotic pressure on both sides of the cell wall having properties of a semi permeable membrane causes moisture removal from the products. The semi-permeable property of cell wall permits migration of water and low molecular molecules to the osmo-active liquid having higher osmotic pressure. Thus, thinner cell sap causes increase in water activity of the medium.

6.5.2.7 Fluidised bed drying:

In this method of drying, products are being dried under fluidized condition in a dryer. The materials are fluidized by drying air with sufficiently high velocity to cause suspension. In this drying process, higher rates of moisture migration takes place. Since every surface of product is in contact with drying air, uniform drying of products takes place. This method is normally used for materials which have high initial moisture content and are lighter and at the same time required to be dried quickly

6.4.2.8 Desiccated air drying:

In this method of drying the ambient air is passed through a desiccated medium or source e.g. silica gel. The desiccator absorbs moisture from the air, as a result, the relative humidity of air is reduced and at the same time there is an increase in its temperature. When such air comes in contact with wet grains, transfer of moisture from wet grains to drying air takes place. The drying action occurs due to convective heat transfer.

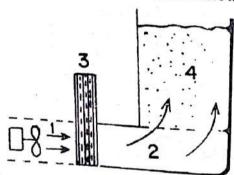


Fig. 6.8 Schematic diagram of desiccated air drying 1.Ambient air, 2.Desiccated air, 3.Desiccated source, 4. Grains in drying chamber.

6.5 · Types of dryers:

Different types of dryers can be categorized as

- Dryers in which products are kept in a bin and the heated or drying
- Dryers in which products are kept moving. The movement of products is by gravity or by some mechanical means and the drying
- Dryer with free falling bed due to gravity and the drying is ventilated
- Dryers in which the products are dried in a state of fluidization by

The different types of dryer are described as follows 6.6.1 Deep bed dryers:

These batch-in-bin dryers are of large capacities of several hundred tonnes. The most common shapes are round or rectangular. An air flow rate of 2.94 to 3.92 m³/min. is recommended. If the moisture content of grains is upto 18%, the layer depth of grain should be limited to 3 m, For grains whose moisture content is above 18%, the maximum depth recommended is 2.5 m. The net perforated area of the floor should be 15% of the total floor area. Air velocity of 300 m/min. through the opening is preferable.

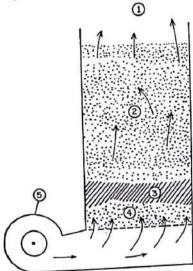


Fig. 6.9 Deep bed dryer's schematic diagram 1. Exit air, 2. Wet grain, 3. Drying zone, 4. Dry grain, 5. Blower.

6.6.2 Flat bed dryers:

The flat bed batch type dryer is similar to deep bed dryers except that the surface area of the dryer is more and the depth of the drying is less. These dryers are of usually 1 to 2 tonne capacity. These are designed for farm level operation. Grains are spread 0.6 to 1.2 m deep over the perforated floor and dried. The main advantage of this type of dryer are

The whole batch is dried quickly and there are less chances of spoilage due to moulding.

- 2. There is less likelihood of over-drying of the grain.
- 3. A lower air pressure is required to force the drying air.

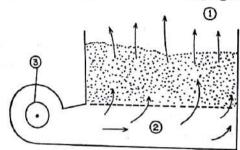


Fig.6.10 Flat bed dryer 1.Exit air, 2.Plenum chamber, 3.Blower.

1.6.3 Continuous flow dryers:

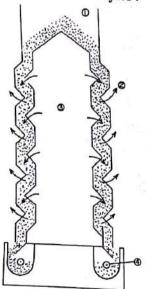


Fig.6.11 Continuous flow dryer (mixing type)

1.Feed hopper, 2.Exit air, 3.Plenum chember, 4.Dry material outlet.

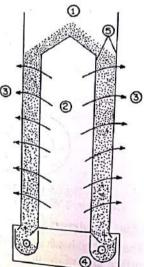


Fig.6.12 Continuous flow dryer
(non - mixing type)

1.Feed hopper, 2.Plenum chember, 3.Exit air, 4.Dry grain outlet,
5.Screened grain column.

These dryers are columnar type in which wet grains flow from the top to the bottom of the dryers. The rate of flow of grains through columns can be regulated by conveyers. These dryers are of two types mixing and non mixing as shown in Fig. 6.11 and 6.12.

- Mixing dryers: If the grains flow in a straight path, the dryer is called a non-mixing type and when the grains are diverted in the dryer, it is called a mixing type dryer. Drying is accomplished by forcing heated air across the falling layers of grains. In these dryers baffles are provided to cause the grains to mix during their downward flow. These dryers use low air flow rates of 50 to 95 m³/min tonne and high drying temperature of 65°C. Zig-zag columns enclosed by screens on both sides are used primarily to achieve mixing action during drying process.
- b) Non-mixing dryers: In these dryers baffles are not provided in the columns and drying takes place between two parallel screens,12 to 25 cm apart. In these dryers high air flow rates of 125 to 250 m³/min tonne can be used. It permits the continuous movement of grains in columns. Drying air temperature of 54° C is used in non-mixing dryers.

6.5.4 Recirculating dryers:

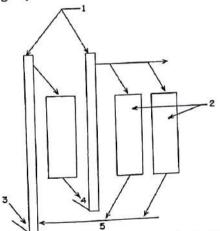


Fig. 6.13 Recirculatory dryer's schematic diagram

1. Elevator, 2. Tempering bins, 3. Wet material, 4. Semidried material, 5. Conveyor

In continuous flow dryers, a multipass procedure is used to avoid excessive drying stress. During each pass, the grains are exposed to the heated air for a short time of 15 to 30 min. and about 1 to 3% of the moisture content is removed in such dryers, drying air temperature of 60 to 80°C is used. Drying is faster and effective because of the continuous movement of grains during the short drying times. Between drying passes, the grain is stored in a tempering bin for 4 to 24 hours to allow the moisture content at the centre and the surface of the grain to equalise.

6.6.5 Lousiana State University (LSU) dryer:

The design of this continuous dryer was developed at the Lousiana State University in the mid 1950, hence called the LSU dryer. This design was developed specifically for rice, to ensure gentle treatment, good grain mixing and good air-to-grain contact. It is a mixing type continuous flow dryer, in which layers of inverted V-shaped channels are installed. The layers alternate between hot air intake and exhaust air outlets and are staggered to provide mixing. The LSU dryer is not high capacity and being used in big commercial rice mills.

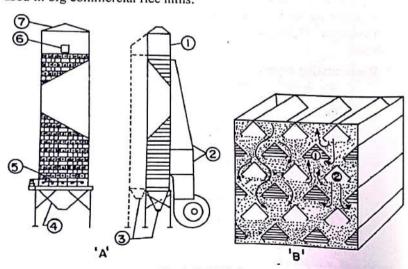


Fig.6.14 LSU dryer (A) 1.Garner, 2.Duct, 3.Dry material outlet, 4.Hopper, 5.Continuous flow, 6.Door, 7.Roof.

(B) Cross - section of drying chamber, 1. Air exhaust, 2. Air intake.

6.6.6 Fluidized bed dryers:

The fluidized bed drying technique holds an important position among modern drying methods. It is used mainly for granular materials nevertheless it is also applicable in the drying of solutions, pastes and liquids sprayed onto the fluidized inert bed. The principle of operation of fluidized bed dryer is to provide sufficient air pressure to fluidize a thin bed of grain/product, giving excellent air/grain contact. Above a certain pressure, related to the weight per unit area of the grain bed, the pressure drop across the bed becomes constant with volume flow rate, so that fast drying can occur. The main advantages of this type of dryer are,

- i. Fluidity of bed facilities continuous and easy equipment performance even on very large scale plants.
- Lack of moving parts.
- iii. Very good condition for mass & heat transfer.
- iv. Provides good mixing i.e. uniformity at drying of the material in the
- By combining high air temperatures and suitable grain tempering, the fluidized bed offers better economy, gentle grain handling and reduced

The drying method is based on ventilating hot air through the bed of product kept on the support grid or the gas distributor. When the air velocity becomes higher than the critical fluidization velocity, the bed progressively expands until it reaches a state that of boiling liquid. This phenomenon is called fluidization.

In commercial rotary dryers the diameter of drum is between 1 to 3 m and the length is from 3 to 6 m. It is operated at slight inclination. The drum rotates on its axis. The grain flows downward through the rotating drum and is periodically lifted by inclined flights, then dropped, ensuring good air /grain contact. However, in commercial practice the main method of drying is convective heating by drying air whereas, in the small scale designs heating is by conduction through the walls of the drum. In small scale rotary dryers, the walls are heated by direct contact with the fuel gases of a combustor, preferably biomass fuel. In Tamil Nadu Agricultural University a continuous type rotary dryer has

been developed. The grains are dried by direct contact with heated sand The dryer is used for drying of parboiled paddy as well as for dry roasting of Bengalgram and other grains.

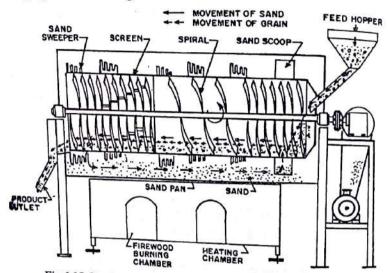


Fig.6.15 Continuous flow heated sand medium rotary dryer.

6.6.8 Spouted bed dryers:

The spouted bed drying principle is similar to that of fluidized bed drying but it is less developed. Instead of fluidizing the whole bed, a jet of air is spouted upwards through a section of the bed, the grain being entrained in the jet and falling out of the spout in a fountain onto the annular region of grain surrounding the spout. The whole bed of grain is continually being heated and dried. Thus the process is energy efficient and uniform in treatment. The grain is automatically tempered during drying

6.6.9 Tray dryers:

In a tray dryer, many shallow trays are kept one above the other with a gap in between in the drying chamber. Tray dryer is generally used for drying of vegetables and similar semi-perishables. The trays may or may not have perforated bottom. Perforated trays are used when the plenum chamber is at the bottom of drying chamber. If the heated air is coming from the sides of drying chamber, the trays may not have perforated bottom. The gap in between the group of trays permits air ventilation. Products are kept in thin layers in the trays.

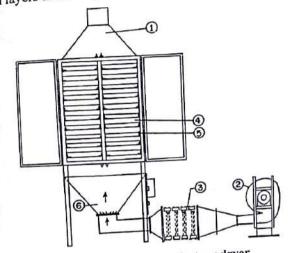


Fig.6.16 Diagram of a tray dryer 1.Exit, 2.Blower, 3.Heater, 4.Inter space between trays, 5.Trays, 6.Plenum chamber

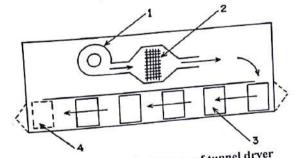


Fig. 6.17 Schematic diagram of tunnel dryer 1.Blower, 2.Heater, 3.Trays, 4.Exit air chimney

It is similar to tray dryer. When the group of trays is stationary, the 6.6.10 Tunnel dryer: system is called a tray dryer but when the group of trays is moving in a tunnel, the system becomes a tunnel dryer.

The flow of heated air in a tunnel dryer may be concurrent or counter current.

EXERCISES

- O.1. Explain the drying process.
- Q.2. What are the advantages of drying?
- Q.3. Enlist and describe different methods of drying.
- Q.4. What are different types of dryers? Explain tunnel dryers in detail.
- Q.5. With the help of neat diagram, explain the Lousiana State University





STORAGE STRUCTURES

There has been a spectacular increase in food grain production in India. The annual production was 232 million tones in 2009-10. However, there has only been a marginal increase in the capacity of structures for grain storage. This has resulted in losses both in a quality and quantity of the harvested grain. The qualitative loss may be due to chemical changes in the protein, carbohydrates and fat and by the contamination of micotoxins, pesticides residues, insect, fragments, excreta of rodents and birds and their bodies. It is reported that on an average a loss of 9.33% per annum occurs in India. It is estimated that about 60% of the total grain produced is retained by the farmers for their food and seeds. The remaining 40% quantity is considered as marketable surplus. The total storage capacity available with various agencies of the Government is of the order of about 15 per cent.

7.1. Existing storage methods:

The existing storage methods are as follows:

- Storing in bags in a house (Farmers level).
- ii. Storing in bags on platform and covering them by polyethylene (CAP
- iii. Storing in bags either in godowns or in Bukhari (Wheat Bhusa
- iv. Storing in indigenous storage structures and traditional devices such as baskets, theka, earthen pots etc. (Farmers level).

7.2. Requirement of good storage structures:

A good storage structure should satisfy the following requirements:

It should provide adequate protection from rodents, birds, insects, mites etc.

- ii. It should permit aeration and fumigation when required.
- iii. It should prevent losses due to moisture and temperature etc.
- iv. It should permit easy inspection.
- It should facilitate proper cleaning and should be self cleaning if it is silo.
- vi. It should be economical on unit storage, cost basis.

7.3. Different storage structures:

Grain is generally stored either in bags or in bulk. A combined system of bag-cum-bulk storage is also practiced in some parts of the country. In villages the bulk storage system is more common than the storage in bags. The side of a bag used for grain storage is large enough to contain about 93 kg. of grain. These bags are made of jute fibers and are commonly known as gunny bags.

The bulk storage of grain is generally done in one of the following storage structures in the different regions of India. Each type of grain is stored in a separate structure

- Bukhari
- Kothar
- 3. Morai
- Bag storage structure
- Cylindrical Grain bins i) Metal bin
- Rectangular grain bins i) Pusa bins
- Bunker storage
- CAP storage structure

7.3.1 Bukhari:

Bukhari is cylindrical in shape and is made of mud and split bamboos. In order to avoid the cylinder coming into contact with the ground, it is always placed on a wooden or masonary platform. The floor of the structure is made of either timber plants or bamboo splits plastered over with mud, mixed with cowdung and paddy straw. The walls of the structure consist of timber or bamboo frame work and bamboo frame work and bamboo matting, over which mud-straw plaster is applied on both the surfaces. Walls are further strengthened by timber posts which are fixed in the ground, extending up to the full height of the walls.

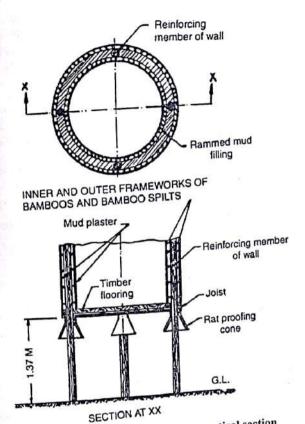


Fig. 7.1: Bukhari Grain Structure-vertical section

In order to provide a smooth surface, a layer about 5cm thick of mud plaster is applied. The walls are made of two sets of sufficiently strong bamboo frame work. The hollow space between the two sets of frame work is filled with rammed mud. The walls are finished on both surfaces with mud plaster. The conical roof is made of bamboo frame work and covered with paddy straw or similar other thatching material. On the top of it, a thick layer of 4 to 5 cm of mud plaster is applied as an additional

The entire structure is placed about 1.5 m above the ground level protection from rains. and is supported by four timber or masonary pillars. For the purpose of loading and unloading the structures, two openings are provided. The one for loading (filling) the grain is provided at 15 cm from the edge of the wall and the other one at floor level, is for emptying it. When the structure is closed, these openings are sealed with wooden planks and mud plaster. Hollow rat proofing cones are placed on all the four pillars so that the rats are not able to climb up.

Bukhari type structures are generally used for the storage of wheat, gram, paddy, maize and sorghum. Their capacity varies from about 3.5 to 18 tonnes. However, the smaller size structures are also used if the quantity of grain to be stored is less.

7.3.2. Kothar:

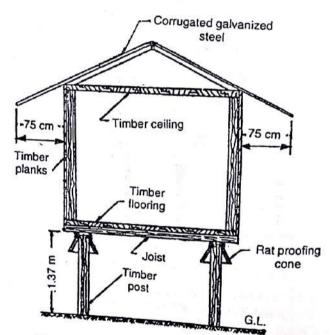


Fig 7.2 Kothar grain structure-vertical section

Courtesy: Indian Standards Institution

These structures are very much like a timber placed on a raised platform which is generally supported by pillars. Both the floor and walls are made of wooden plants whereas the thatched or tiled roof is placed over it as protection from the sun and rains. The improved type of storage

structure is mainly made of 5 cm thick wooden planks and wooden beams. The walls and floor are so made that no gap exists between the planks. The gabled roof on the top may either be made of planks or corrugated metal sheets. It should have sufficient over hang on all sides. However, 22 gauge corrugated metal sheet is preferred to planks. Under all conditions the structure should be leak-proof as well as free from the danger of moisture rising from the ground surface.

Kothar type of storage structures are used for the storage of paddy, maize, sorghum, wheat and barely. Their capacity ranges from 9 to 35 tonnes. They are commonly built in the rural areas of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh and Uttaranchal.

7.3.3. Morai :

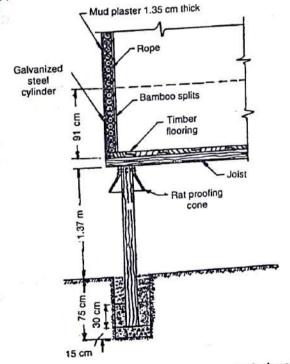


Fig. 7.3 Morai grain storage structure-vertical section

Courtesy: Indian Standards Institution

The improved type of structure consists of a circular wooden plank floor supported on pillars by means of timber joints. The planks are joined together with lap joints. All around the wooden floor a 22 gauge corrugated metal cylinder of 90 cm height is nailed to it. The edge of the cylinder is flushed with the bottom end of the floor. Inside the cylinder, 7.5 cm diameter ropes made of paddy straw or similar material is placed, beginning from the floor level up to a height of 90 cm. Then bamboo splits are placed vertically along the inner surface without leaving any gap between them. The height of the bamboo splits is equal to the total height of the structure, To provide a smooth surface, about 1 cm thick layer of mud plaster is applied over the rope.

The Morai type of structure is used for the storage of paddy, maize and sorghum in the rural areas of eastern and southern regions of India. Its capacity varies from 3.5 to 18 tonnes. These structures are very similar to the shape of an inverted cone.

7.3.4. Bag storage structure:

In constructing the structure special care is taken to make the sides, floor and roof moisture proof. Each of the structures is provided with two large size doors of 2.4 m \times 2.4 m and top ventilators. Each door is provided with a light over-hanging hood 3.6 m long and 2.4 m wide. A ground ventilator having an opening of 30 cm × 30 cm is provided below each corresponding top ventilators. The top of the ventilator is kept at a height of 60 cm above the floor level.

In order to ensure that the floor is damp-proof, it is made of different materials in six layers. The walls are made of bricks or stores laid either in lime mortar (1:2) or cement mortar (1:6). The thickness is restricted to a minimum of 37.5 cm or maximum of 45 cm. The height of the walls on which the trusses are placed is kept about 5.5 m. The roof is either gabled or flat. A flat roof is more durable as it is made of either reinforced brick or reinforced concrete of about 10 to 12.5 cm thickness. The terracing on the roof is made of brick ballast, surkhi and lime in the proportion of 3.5:1:1,

These structures are generally used for the storage of 25 to 500 tonnes of grain. The length of the structure is about twice the width or greater than

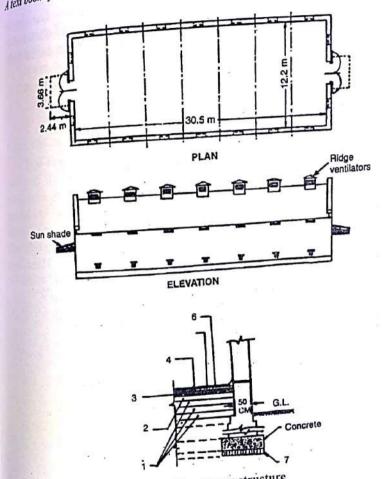


Fig 7.4 Bag storage structure Courtesy: Indian Standards Institution

7.3.5. Cylindrical Grain Bin:

The complete structure including its foundation is made of reinforced concrete. The minimum height of the bottom edge of spout should be about 1.2 m above the ground level. The entire structure rests on supporting columns. There are two openings provided in the structure for filling in the grain and taking it out. The top hole is made large enough to let a man enter for cleaning purposes. The site of the outlet is comparatively smaller. It is placed at a point where the slope from all sides of the floor converges. The roof on the top is provided with enough slopes on all the sides and it overhangs to the extent of about 30 cm. The structure is similar as bulk

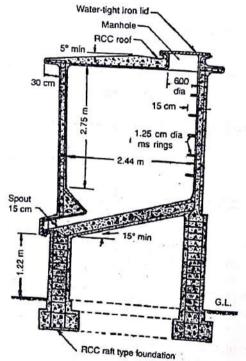


Fig 7.5 Bulk storage structure Courtesy: Indian Standards Institution

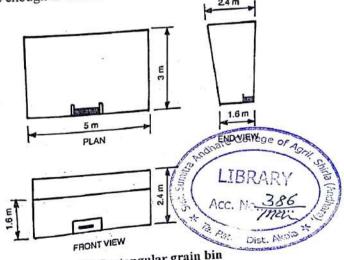
Depending upon the size, the capacity may vary from 10 to 40 tonnes. These bins are used both as indoor or outdoor storage structure.

Metal bins: Metal bins are the most accepted bins for small quantity household food grain storage and also large quantity bulk storage where mechanical handling is considered essential. Metallic silos are preferred for transit storage at dockyards, rice mills, dal mills and solvent extraction plants. These bins are made of iron/steel, tin or aluminium sheets. These are mostly cylindrical in shape having their

top and bottom covered with circular metal sheets. Arrangement for filling grain from the top and emptying from the lower side through an outlet are commonly accepted and convenient systems. It is desirable to keep these bins airtight by using rubber gaskets or water proofing paper at the lid. 'PARATH' an insecticide of negative origin is used to control weevils in indoor metal bins.

7.3.6. Rectangular grain bin:

The size of the bin is determined on the basis of expected average yield of the crop from the total area under the particular crop. The bin walls are made 10 cm thick laid in cement mortar of 1:3 ratios. The bin walls are kept 2.4 m high near the outer wall dropping down to 1.6 m in front. The front wall is provided with a rectangular hole on the floor level for taking out the grain. The hole can be closed or partially opened from the inside of the bin by a wooden board. A wooden plank of size 60 cm x 45 cm is large enough to close a hole of 45 cm x 40 cm side.



.Fig. 7.6 Rectangular grain bin

The height of the bin wall is made low so that workmen may drop the head load of grain directly into the bin. The capacity required will vary with crop. For example wheat requires barely 1.75 cu.m. volume per tone of grain.

Pusa Bin: The Pusa bin is a simple moisture free bin made of unbumt bricks having grain holding capacities from 0.5 to 4.0 tonnes. It is recommended as an indoor structure for small farmers or families desirous of storing food grain from one season to the next. While constructing the bin, polyethylene film is placed between the two layers of mud bricks or mud walls such that moisture migration could be stopped. The film being embedded inside the wall, remains protected from abrasion and mechanical damages. The length, width and depth ratios of the bins range from 1:1:2 to1:1:1 depending upon the availability of space and quantity of grain to be stored. These bins were popularized around Delhi with good success.

7.3.7. Bunker storage:

This is used for long term storage of a larger volume of grains. It has proved successful as a means of storing grain safely and economically. Controlling the insects and moisture level, the losses can be reduced up

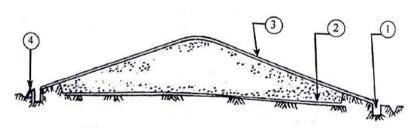


Fig.7.7: Schematic diagram of bunker storage 1. Trench for burying cover 2. Plastic ground sheet 3. Top cover 4. Drain.

7.3.8. CAP storage structures:

The word 'CAP' is used for cover and plinth, plinth from the bottom and cover from the top. This type of open storage is considered as transit storage and is cheaper as compared to conventional bag storage godowns. The cover is rectangular in shape having four sides made from polyethylene film of 1000 gauge, leaving the bottom side open. Normally the stack is built over a space of 9.11 m x 6.1 m with a height of 18 bags which gives the storage capacity of around 150 tonnes. The cover having a dimension of 9.4 m x 6.4 m x 5.5 m normally weighs around 52 kg. Sometimes smaller covers are used for covering the stacks in covered

verandah of conventional godowns. Such covers are called 'Varandah veranual covers. In storage of food grains under verandah covers, the stacks are built to a height up to 7 bags having an average capacity of 24 tonnes.

While constructing the CAP structure the following steps are required to be followed:

- Select a high elevated ground and make it level.
- Wooden sleepers are spread with one or two layers of bamboo mat cover on the top as dunnage.
- iii. The gutters are provided all around the area to drain off rain water
- The stacking is done to the height up to 18 bags on the dunnage and covered with polyethylene.
- v. The stacks are covered with polyethylene covers and tied with ropes to prevent from blowing off with high velocity wind.

EXERCISES

- Q.1. What are different existing storage methods?
- Q.2. What are the requirements of good storage structures?
- Q.3. Enlist different storage structures.
- Q.4. Explain bag storage structure with neat sketch.



The few important definitions in this regard are as follows:

- Cleaning: Cleaning in agricultural processing generally means the removal of foreign and undesirable matters from the desired grains/ products. This may be accomplished by washing, screening, hand
- ii) Grading: Grading refers to the classification of cleaned products into various quality fractions depending upon the various commercial values and other usage.
- iii) Sorting: Sorting refers to the separation of cleaned product into various quality fractions that may be defined on the basis of size, shape, density, texture and colour.
- iv) Scalping: Scalping refers to the removal of few large particles in an initial process.
- v) Screening: Screening is a method of separating grain/seed into the two or more fractions according to size alone. For cleaning and separation of seeds, the most widely used device is screen.

8.2.1. Air screen cleaners :

The screens used in combination with air blast perform satisfactory cleaning and separation operations for most of the granular materials. The air-screen cleaner uses three cleaning systems; blowing or aspiration, scalping screens and grading lower screens. The air-screen grain cleaner can be classified in two distinct types based on movement of the screening

- Vibratory screen
- ii) Rotary screen

8.2.1.1. Vibratory air-screen cleaner:

The screening unit is composed of double or multiple (up to 8 number) screens. These screens are tightened together and suspended by hangers in such a manner that these have horizontal oscillating motion and slightly vertical motion. The two motions in combination move the grain down the screen and at the same time toss sufficiently above the screen so that the bed of grain is properly stirred. The slope of the screen is adjustable to control the rate of downward travel of the grain. The screens are available in various shapes like round, triangular or slotted holes. Sometimes the holes of the screen are clogged when fine degree of sorting is made by

the machine. To avoid the clogging, the screens are generally fitted with a brush which moves under the screen and pushes the clogged material back through the screen.

a) A simple vibratory type air-screen cleaner:

This cleaner is as shown in Fig. 8.1. It is a two screen machine fitted with aspirator to such the lighter materials. The grain passes from the feedhopper over baffle plates to the upper screen. Light particles are sucked away by aspirator during the operation. Coarse impurities such as stores, straw particles etc. are screened off by upper screen and discharged out through an outlet. The grain falls through on to the lower screen, where the sand and the dust particles are screened off. The grains leave the machine through discharge funnel. While passing through the funnel the grains are again cleaned by upward draft of air in the ascending separator. During this process the remaining light impurities and shriveled grains are sucked away and the light impurities are removed by cyclone separator to which dust bags are attached for the collection of the impurities.

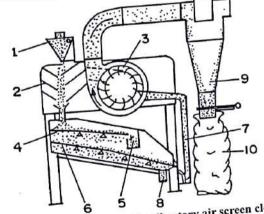


Fig. 8.1 Schematic diagram of a vibratory air screen cleaner 1. Feed hopper, 2. Baffle plate, 3. Blower, 4. Upper screen, 5.Discharge channel, 6.Sand sifter, 7.Ascendeing separator, 8.Discharge funnel, 9.Centriclone, 10.Dust bag.

b) A pedal cum power operated air screen grain cleaner : These types of cleaners can be operated manually either using hand or pedal system. The capacity of such cleaners is lower than the power operated machines. The machine is made up of mild steel and consists of a grain hopper, with feeding mechanism, sieve box on hanging shoes, blower unit, driving and eccentric unit. The cleaner can be operated either

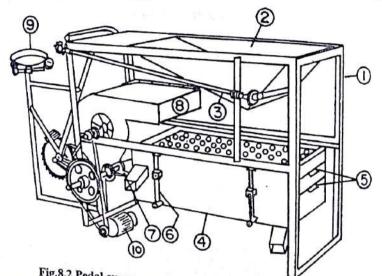


Fig.8.2 Pedal cum power operated air screen grain cleaner 1.Main frame, 2.Hopper, 3.Feeding mechanism, 4.Sieve box, 5.Scalping and grading sieves, 6. Shoe for sieve box, 7. Eccentric unit, 8. Blower, 9. Cycle seat, 10. Electric motor.

8.2.1.2. Rotary screen cleaner:

The rotary screen cleaner has normally circular decks. Their motion is circular in horizontal plane. These have either single or double drum.

The machine consists of a rotary screen, aspirator and hopper and equipped with an electric motor which gives drive to the rotary screen and the aspirator. The mixture is fed into the hopper. The sound grains pass through the screen perforation into the centre of the screen drum, whereas oversized material is retained above and pass out through an outlet. The sound grains come out at the centre side of the screen drum rotating at low speed and fall onto the vibratory screen which remove the dirt particles. The light particles like straw and dust are sucked away by the aspirator and discharged through the aspirator outlet. The cleaned grains are delivered

A double drum rotary screen cleaner has two rotary screens and other components are same as in the case of single drum rotary screen cleaner. The two screens rotate in opposite direction to each other.

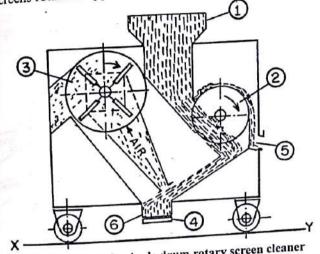


Fig. 8.3 Diagram of a single drum rotary screen cleaner 1.Feed hopper, 2.Rotary screen, 3.Aspirator, 4.Discharge chute, 5. Over size foreign matter outlet, 6. Vibratory screen.

8.3. SEPARATORS:

It is very difficult to clearly differentiate among the process of cleaning, grading and separation because all of these are carried out simultaneously with common procedures.

The operation of cleaning, grading and separation of the products are performed by exploiting the difference in engineering properties of the materials. These products may be used either for food or seed purposes. Various types of cleaning, grading and separation equipment have been designed and developed on the basis of properties of product to be handled. These properties are as follows.

- Size i)
- ii) Shape
- Specific gravity or weight iii)
- Surface roughness iv)
- Aerodynamic properties V)

Ferro-magnetic properties

vii) Colour

viii) Electrical properties

8.3.1. Separation based upon size :

This separation can be performed by using following equipments.

a) Spiral separator:

The spiral separator separates the grain as per their roughness. The main component of the separator is a stationary, open screw convener standing on one end. The mixture is fed at the top of the unit. The round materials of the mixture pick up speed as they slide or roll down the inclined surface until their centrifugal force becomes sufficient enough to throw them

While the non-round materials are caught in the inner helix and are discharged through a

There is no moving part in the spiral separator. The rate of feeding is the only adjustable component. The feeding should be such that each grain/particle rolls independently for effective separation. The main limitation of the spiral is lack of flexibility.

Separation of mustard, rape, soybean, wild peas or other round seeds can be performed for wheat, flax, oats etc. This service is less versatile as compared to other mechanical cleaners but it is simple, inexpensive and quite useful for seed cleaning purposes.



8.3.2. Separation based on density or specific gravity of the material:

This separator works on two principles. The characteristics of grains to flow down over an inclined surface; the floatation of the particle due to

The main part of the device is a triangular-shaped perforated deck. The deck is properly baffled underneath to ensure uniform distribution of air over it. The pressure or terminal velocity of the air rising through the deck is controllable very closely within a wide range

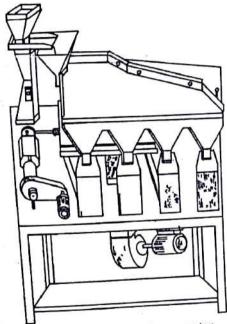


Fig.8.5 Specific gravity separator

The mixture of grain is fed into the feed box. The air is blown up through the porous deck surface and bed of the grain by a fan at such a rate that the material is partially lifted from contact with the deck surface. The lightest materials are lifted to the top of the stratified mass. The heavier particles are not lifted by the air. The stratified mass moves along the direction of conveyance due to oscillating motion of the deck and is discharged at the right edge of the deck.

8.3.3. Separation based on difference in shape and surface feature of the material.

This technique of separation is used when all other methods fail.

a) Inclined draper:

The mixture to be separated is fed over the centre of an inclined draper belt moving in upward direction. The round and smooth grain roll or slide down the draper at faster rate than the upward motion of the belt and these are discharged in a hopper. The flat shape or rough surfaced particles are carried to the top of the inclined draper and dropped off into another hopper.

The belts of different degrees of roughness may be used as a draper for separate materials. If rolling tendencies of the grain are predominant, the rough canvas belt may be used. The smooth, plastic belt may be used in case sliding action is desired for the lower fraction. Feed rate, speed of draper and angle of inclination are other important variables for effective separation of dissimilar materials.

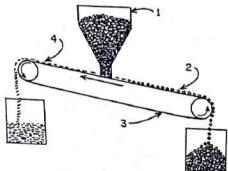


Fig.8.6 Inclined draper 1.Feed hopper, 2.Round seed, 3.Canvas draper, 4.Flat seed/impurities.

The feed rate is kept low enough to give opportunity to each grain for separation. The speed of the draper may be varied to simulate with the length of incline. The angle of inclination is adjusted to assure rolling or sliding of the desired lower fraction. To increase the capacity of the separator number of belts may be used one above another in a single

8.3.4. Separation based on the basis of surface feature and stickiness

a) Magnetic separator:

As the grains do not contain any free iron therefore they are not

attracted by the magnet. A selective pretreatment of mixing finely ground iron powder to feed mass is given. The grain mixture is fed to a screw conveyor or other mixing device that tumbles and mixes the grain with a proportioned amount of water. Due to moisture, iron powder adheres to rough, cracked, broken and sticky seed coats. Moisture does not remain on smooth grains so no iron powder adheres to smooth surfaced grains. The grain mixture is fed onto the top of a horizontal revolving magnetic drum, the smooth grains that are relatively free of powder fall along the drum simply by gravity. The materials with iron powder are attracted by the magnetic drum and stick to it and are removed by rotary brush or break in the magnetic field.

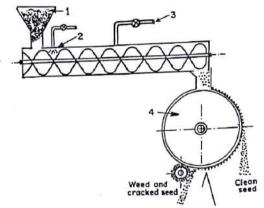


Fig.8.7 Magnetic Separator 1.Feed hopper, 2. Water spray, 3.Iron powder mixing, 4.Magnetic drum

Most of magnetic separators have two or three revolving magnetic drums operating in a series. The grain mixture is passed over these magnetic drums to increase the efficiency of operation. The extent of difference in seed coats, amount of water mixed, amount of iron powder and thoroughness of powder-water mixing operation affect the degree of successful separation by magnetic separators.

8.4 Seed size reduction:

Milling is a general trade name which is normally means reduction of food grain into various end products like meal, flour, splitted products etc. Milling includes cleaning, grading, separation, mixing, pearling, polishing,

dehusking, size reduction etc. The meaning of the term milling varies with the crop. For example milling of wheat refers to a grinding operation to produce flour, whereas in rice industry milling refers to overall operations in a rice mill i.e. cleaning, dehusking, paddy separation, bran removal and grading of milled rice. Milling also refers to extraction of juice, oil or

8.4.1 Principles of size reduction:

Crusher and grinders are the equipment mostly used for size reduction of agricultural products. An ideal size reducer should fulfill the following

- Large capacity
- Should yield a predesired sized product or range of size.
- Small power input requirement per unit of product handled
- Easy and trouble free operation.

Usually the performance of any milling equipment is compared with respect to an ideal operation as standard. The characteristics of the actual equipment are compared with those of the ideal unit.

Size reduction procedures:

The size of agricultural products may be reduced by several ways but mainly the following four methods are used in size reduction machines.

- 1. Impact: In impact a sudden blow of force is applied on a material so that it cracks e.g. cracking of nut, de-husking of paddy with centrifugal dehusker. In hammer mill also size reduction is done with the help of impact
- 2. Cutting: General device used for cutting is knife. With the help of sharp and thin edge of the knife the product size reduction is done. Size reduction in this case depends upon the required nature of end product e.g. size reduction of vegetables and fruits.
- 3. Compression: Material fails when an external force is applied on a material in excess of its crushing strength and the material breaks or rupture in to many pieces. The size and shape of the end product in crushing are irregular. Crushing depends upon the characteristics of material and amount of crushing force applied. e.g. making flour, meal and grits. Crushing is also used in juice extraction, oil extraction.

4. Shearing: Shearing is a combination of cutting and crushing. In the size reduction machine knife and a bar is used to do the needful shearing action. Sharp edge is thin so that material is cut down into pieces, whereas the dull edge do the crushing of the material.

8.4.2. Equipments:

The equipments for size reduction are grouped as follows.

- Crushers
- Grinders
- Fine grinders
- Cutting machines

Some of the equipments are described in the following paragraphs.

8.4.2.1. Jaw crusher:

These types of reducing machines squeeze or press the material until it breaks. Crushers are mostly used to break large pieces of solid materials into small lumps. Crushers are used in industrial operations like mines etc. Use of crushers in agricultural operations is limited.

Lime and other stores are first reduced by the jaw. In a jaw crusher feed is admitted between the jaws, which are open at the top like 'V'.

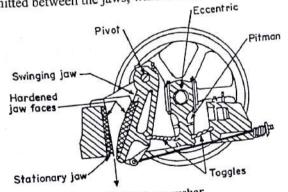
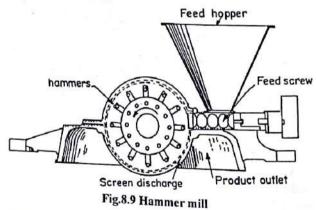


Fig.8.8 Jaw crusher

One of the jaws is fixed and somewhat vertical, while the other is the swinging jaw. This jaw reciprocates in a horizontal plane and makes an angle of 20 to 30° with the fixed jaw. The movable jaw is operated by an eccentric unit so as to impart great compressive force. The solid which has to be broken is caught between the two jaws. Large lumps of solid materials are caught between the upper parts of the jaws and subsequently broken and dropped into the narrower space below. The broken pieces are further reduced next time when jaws come closer. The number of strokes given to the movable jaw by eccentric unit ranges between 250 to 400 times per minute.

8.4.2.2. Hammer mill :

Hammer mills are used for various types of size reduction jobs. These mills contain a high-speed rotor, rotating inside a cylindrical casing. The shaft is usually kept horizontal. Materials are fed into the mill from the top of the casing and is broken by the rotating hammers and fall out through a screen at the bottom. The material or feed is broken by fixed or swinging hammers which are pinned to a rotor. The hammers are rotated between 1500 to 4000 rpm, strike and grind the material until it becomes small enough to pass through the bottom screen. Fineness of grinding is controlled by the screen size.



Hammers are either rigidly fixed to the shaft or swinging. In case of swinging hammer mill there is less chances of damage of hammer if some unbreakable solid material comes to milling chamber along with feed. The capacity and power requirement of hammer will depend on the nature of feed to be ground. Commercial mills reduce solids between 60 to 240 kg/kWh of energy consumption. Hammer mills are used for poultry feed grinding, spice grinding. It was also found suitable for grinding of wet sorghum and millets and also for potato, tapioca, banana and similar flour making.

The ball mill is a cylindrical or conical shell slowly rotating about a 8.4.2.3. Ball mills : horizontal axis. Half of its volume is filled with solid grinding balls. The shell is usually made of steel lined with high carbon steel plate, porcelain or silica rock. For medium and fine reduction of abrasive materials ball mills is used. In a ball mill size reduction is achieved by impact of the balls when they drop from near the top of the shell. The balls are carried up the side of the shell nearly to the top. By gravity the balls drop on the feed underneath. The energy consumed in lifting the balls is utilized for grinding job.

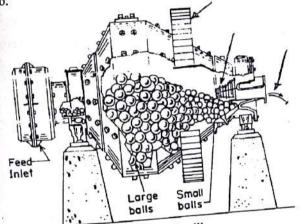


Fig.8.10 Ball mill

When the ball mill is rotated, the balls are carried by the mill wall nearly to the top, where they are released by gravitational pull and drop to the bottom and picked again. Centrifugal force keeps the ball in contact with the mill wall. Most of the grinding is done by the impact of balls. In case of two high speed balls stick to mill wall and are not released. This is a stage of centrifuging. The rotational speed at which centrifuging occurs is known as critical speed. The operating speeds must be kept less than the critical speed. The speed at which the outermost ball released from the mill wall depends on the interaction of gravitational and centrifugal forces. The critical speed can be determined by the following equation

$$n_c = \frac{1}{2\pi} \sqrt{\frac{g}{R-r}}$$

Where, $n_c = Critical speed$, revolutions/sec

g = Acceleration due to gravity, 9.8 m/s²

R = Radius of the mill, m

r = Radius of the ball, m

The rotational speeds of the ball mills (n_o) are kept at 65 to 80% of the critical speed, with the lower values for wet grinding in viscous suspension.

Problem 1. What would be the operating speed of rotation in revolutions per minute of a ball mill of 2000 mm diameter charged with 100 mm balls? The ball mill is grinding solid matter.

Solution: Given

$$R = 2000 \text{ mm} = 2 \text{ m}$$

$$r = 100 \text{ mm} = 0.1 \text{m}$$

The critical speed

$$n_c = \frac{1}{2\pi} \sqrt{\frac{g}{R-r}}$$

Substituting the values in above formula

$$\therefore n_e = \frac{1}{2x3.1416} \sqrt{\frac{9.8}{2-0.1}} = 0.36144 \text{ revol./s}$$

$$n_c = 0.36144 \times 60 = 21.58 \text{ rpm}$$

Therefore the operating speed for solid matter grinding,

$$n_o = n_c \times 0.8 = 21.58 \times 0.8 = 17 \text{ rpm Ans.}$$

Prob. 2. What would be the critical speed and operating speed of rotation for wet grinding in viscous suspension by a ball mill of 1600 mm diameter charged with 75 mm balls?

Ans. Given,
$$R = 1600 \text{ mm} = 1.6 \text{ m}$$

$$r = 75 \text{ mm} = 0.75 \text{ m}$$

$$\therefore n_{c} = \frac{1}{2\pi} \sqrt{\frac{g}{R-r}}$$

$$\therefore n_c = \frac{1}{2x3.1416} \sqrt{\frac{9.8}{1.6-0.075}} = 0.4034 \text{ revol/s}$$

$$\therefore$$
 n_c = 0.4034 x 60 = 24 rpm

Therefore, the operating speed will be 65% of critical speed $n_0 = 24 \times 0.65 = 16 \text{ rpm}$ Ans.

EXERCISES

- Q.1. What are different unit operations in seed processing?
- Q.2. Differenciate between cleaning and grading.
- Q.3. Enlist different ways in which separation of material can be done.
- Q.4. Explain rotary screen cleaner with neat sketch
- Q.5. State the principle of size reduction
- Q.6. Enlist and explain different equipments used for size reduction.





GRADING MACHINERIES FOR FRUITS & VEGETABLES

The most important factor in determining the quality of processed fruit and vegetable products is careful grading. The various parameters are used symmetry, texture, freedom from damage by mold or insects; while odor and flavor are important properties that are taken into consideration

9.1 Object of Grading:

Grading of the raw product before processing results in greater uniformity of finished product and in standardization and improvement in methods of preparation, processing and preservation. It gives the consumer several grades that range in price according to grade. Standard quality peas are a good, wholesome and very nutritious food, but cost less than the fancy. In spite of the fact that the label will usually informs the purchaser of the grade of the product, many housewives buy a nationally advertised brand on the assumption that it is of highest quality, often this assumption is correct, but not necessarily so.

The fruits should be graded roughly for quality. The overripe boxes of fruits should be separated from those of proper maturity. The women employed in cutting and peeling the fruit sort it for quality, usually before peeling or cutting and some fruits are again sorted on broad, slowly moving belts. Careful sorting is essential to success in commercial canning. Vegetables must be sorted according to maturity, freedom from blemishes etc. Peas are graded, by flotation in brine, according to maturity and are sorted on a belt to remove bits of pod, vine, weed seeds, weed pod and burs. Corn must be sorted by hand according to maturity before it is cut

9.2 Size Grading of Fruits:

Grapes, Cherries, Plums, Olives and Berries are graded for size whole, white apricots and peaches are graded after cutting in half or other halving and peeling. Pears are graded for size mechanically before peeling.

Most of the fruits are graded over vibrating screens with circular openings of various sizes. The unit of measurement for these holes in most cases is 1/32 inch. The screens are normally five or six in number and are interchangeable so that single grading machine can be adjusted for different varieties of fruits. The screen is usually made of copper.

9.2.1. Screen Grader :

Large sizes of fruits are removed first in some grades. This is achieved by allowing the smaller sizes to fall through the first screen and allowing the largest size to pass over the end of this screen, where the fruit is conveyed to the canning tables by a belt. Same way the smaller grades of fruit are separated successively. In second method of grading the small sizes are removed first and the largest size is allowed to drop progressively from one screen to the next and finally to pass over the last screen. This result to unnecessary agitation of fruits, which may result in softening or brushing.

9.2.2 Roller Grader:

This grader consists of two rollers. The diameter of each roller is about 2 inch. Both rollers revolve from each other. The rollers are closer together, at the upper end than at the lower end. As the fruit passes along these rollers first smaller fruit is dropped and is removed separately. The largest size fruit get chance to drop through the roller at the end of the rollers and removed separately. Roller grader is suitable for spherical (round) and unpeeled fruits. This type of grader is used to grade peaches, apricots, oranges and olives.

9.2.3 Rope or Cable Grader:

Olives are usually graded for size by travelling, diverging steel end less cable. For grading pears rubber cables are used. The distance between the cables is adjustable.

9.2.4 Weighed Grader:

For grading apples and oranges weight grader are used, which grades the fruit by its weight. Individual fruit fall into travelling canvas pockets placed at one end of short counterpoised rods. The rods rest on a long iron strip, which serve as a fulcrum. As the fruit is carried along the grader, the distance of the fruit from the fulcrum becomes more. The cup holding the fruit tilts as the leverage of the fruit becomes greater than that of the counterpoise. In this type of grader the heaviest fruit is removed first and the lightest fruit at the last.

9.3 Grading of Vegetables:

Beets, asparagus, peas, string beans and cucumbers are graded for size either by screens, cable and other graders or by hand. The method of grading and grade designation vary with the vegetable concerned. Asparagus spears are sorted for size and colour "by eye" into three classes, The size graders for green beans consist of a revolving cylinder with slots of various diameters through which the beans fall on to conveyor. Carrots are size graded in order to separate the young, small sizes from the larger. A common sizing being is 1 inch. Lima beans are graded for size over screens having openings of 24/32, 30/32, 31/32 and 32/32 inch diameter. The various sizes are known as Tiny, Fancy, Medium, Standard and Mammoth. Beets are graded roughly into three size classes by a rod-andreel sizer, the rods running lengthwise of the grader and diverging to give three size groups. The peas are graded for size after flotation separator treatment. Size grading is usually done by passing the peas through a long slowly revolving screen cylinder. In some graders the smallest peas are removed first, in other the largest sizes are removed first.

EXERCISES

- Q.1. What is object of grading.
- Q.2. What are different equipments used for size grading of fruits?
- Q.3. Write in brief about grading of vegetables.





STUDY OF QUALITY STANDARD

10.1 FOOD QUALITY AND STANDARDS:

The government plays an important role in developing standards and controlling the quality of food. National standards are set to ensure fair food trade practices and safeguard the consumers' health. The standards for quality of food and food products have been laid down by statutory bodies. Some of these are:

1. Prevention of Food Adulteration Act (1954) :

Standards for quality of different food and food products have been established which are revised from time to time by the Central Committee for Food Adulteration Act. The main objective of this PFA Act is to obtain a minimum level of quality of food stuffs attainable under Indian conditions.

Fruit Product Order (1961, amended):

The fruit Product Order (FPO) stipulates minimum standards for the quality of various fruits and vegetables products manufactured in the country. The order specifies standards of sanitation and hygiene to be followed in factories, and gives directions regarding packaging, marking and labeling of containers. Packing of vegetables and fruits of a standard below the minimum prescribed standards is a punishable offence by this law. Under this act, every manufacturer must obtain a license before starting the processing of vegetables and fruits and the product should confirm to the standards prescribed under this law.

Meat Product Order:

This order specifies the standards for procedures to be adopted for the selection of disease-free animals, slaughter house practices, treatment of the meat to maintain quality of meat.

The Agmark Standards:

These standards are set by the directorate that defines standards for the quality of cereals, legumes, oilseeds, oils, butter, ghee, eggs etc. and provides or the classification of the commodities into various grades depending on the quality.

The several grades are: special (Grade I), good (Grade II), fair (Grade III) and ordinary (Grade IV). The Agmark gives the consumer an assurance of the quality according to standards laid down.

Bureau of Indian Standards:

The ISI mark on any article of food is a guarantee of good quality in accordance with standards prescribed by the Bureau of India Standards for that commodity. The ISI and Agmark standards are not mandatory; they are purely voluntary. These express degrees of excellence above PFA standards.

Codex Alimentarious:

The Codex Alimentarious Commission, which is the principle organization of the joint FAO/WHO. Food Standrds Programme Formulates, food standards for all the major foods for international markets. It also includes standards in respect of food hygiene, food additives, pesticide residues, contaminates, labeling, presentation and methods of analysis and sampling.

10.2 FOOD ADULTERATION:

Food adulteration may be defined as the process by which quality of the food stuffs is reduced either with non edible or inferior quality food material or by removal of vital element of the food. Putting up decomposed food for sale, misbranding, or giving false labels, addition of toxicants, packaging and preparation of food under insanitary conditions, food from diseased animals are also considered as food adulterations by 'Prevention of Food Adulteration Act', 1954. Adulteration harms the consumers in two

- i) he pays more for a food or food product of inferior quality and
- ii) some of the adulterants are injurious to health, may lead to death, e.g. adulteration of mustard oil with argemone oil causing

Therefore, consumer must not only be vigilant to safeguard family's health but in case of any doubt one may conduct few qualitative tests to detect adulteration in house hold items. Buying food or food products from a reputed and reliable source after careful checking before purchase and insisting on certification mark like AGMARK, FPO (Fruit Product Order) & ISI will all minimizes the risk of purchasing foods of inferior quality.

- HACCP (Hazard Analysis Critical Control Point) it is related with food safety.
- HACCP is an abbreviation of Hazard Analysis Critical Control Point.
- HACCP is a system that leads to the production of microbiologically safe foods by analyzing for the hazards of raw materials.
- HACCP Principles: HACCP consists of following seven principles-
- Assess the hazards of risks associated with the growing harvesting, raw materials, ingredients, processing, manufacturing, distribution, marketing, preparation and consumption of the food in question.
- Determine the CCP (S) required to control the identified hazards.
- Establish the critical limits that must be met at each identified CCP.
- Establish procedures to monitor CCP (S)
- Establish corrective actions to be taken when there is a deviation identified by monitoring a given CCP.
- Establish effective record keeping systems that document the HACCP
- Establish procedures for verification that the HACCP system is working correctly.

ISO - International Standard Organization

It is Quality Management System (QMS) which deals with quality of product and service.

ISO 9000 deals with quality of product and service.

ISO 14000 deals with environmental issues.

ISO 18000 deals with worker's safety.

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10.3 E.P.O. SPECIFICATIONS FOR FRUIT & VEGETABLE PRODUCTS

Table 10.1: Specifications for fruit syrup, crush, squash, nectar, cordial, juice, aerated water containing fruit juice or pulp, ready-to-serve beverage, fruit juice concentrate, jam, jelly, marmalade, cheese, preserve, chutney, etc.

Product	Specifications			
(Prepared from any suitable fruit and variety)		Minimum % of fruit juice or prepared fruit in final product (w/w)		
Fruit syrup	65	25		
Crush	55	25		
Squash	40	25		
Fruit nectar (excluding orange and pineapple nectars)	15	20		
Orange and pineapple nectars	15	40		
Mango nectar	15	20		
Cordial	30	25		
Unsweetened juice	Natural	100		
Sweetened juice	10	85		
Ready-to-serve fruit beverages including aerated water containing fruit juice	10	10		
Barley water	30	25 (minimum % of barley starch 0.25)		
Fruit juice concentrate	32	100		
Jam and fruit cheese	68	45		
Fruit jelly and marmalade	65	45		
Fruit preserve	68	55		
Fruit chutney	50			
Synthetic syrup/sharbat (prepared from herbs, flowers or essences)	65	40		

Table 10.2: Specification for candied and crystallized or glazed fruits

Product (Prepared from any	Specifications	
suitable fruit and variety)	Total sugar (%)	Reducing sugar as % of total sugar
Candied and crystallized or glazed fruit and peel	Not less than 70	Not less than 25

ple 10.3: Specifications for bottled or canned fruits and vegetables

Table 10.3: Specification	Specifications 1. Head space in the can shall not be more than
Product	1. Head space in the can share
Bottled or canned fruit	 The drained weight of the fruit shall not be less than 50 per cent and the fruit should be firm. No preservative shall be added. No artificial colour shall be present, except in case of peas where permitted colour may be added. The can shall not show any positive pressure at sea level and shall not show any sign of bacterial growth when incubated at 37°C for a week.

Table 10.4: Specification for tomato products

Product (Prepared from any suitable	soluble solids (%)	Mould Count	
variety) Tomato juice	-	Not in excess of 30 per cent of the field examined.	
Tomato soup Tomato puree	2005 2000/200	Not in excess of 60 per cent of the field examined.	
Tomato paste Tomato ketchup/ sauce	25 (Minimum acidity as acetic acid 1.0%)	Not in excess of 40 per cent of the field examined. (Yeast and spores not in excess of 125 per 1/60 mm ³ . Bacteria not in excess of 100 million per c.c.)	
Sauces (other than tomato and soybean	15 (Minimum Acidity as acetic acid 1.2%)	Not in excess of 40 per cent of the field	

Important considerations

- 1. In case of RTS containing lime juice the minimum content of juice shall be 5%.
- 2. The container of synthetic syrup shall not bear any label, which leads the consumer into believing that it is a genuine fruit product. In addition the label shall have the word 'Synthetic' distinctly and clearly displayed on it. If the product declared as 'Synthetic' syrup does not contain any fruit juice as prescribed above, the product shall be clearly marked as 'Contains no fruit juice'.

- 3. Peas or any other products, which have been dried or otherwise processed before canning, must be described as 'Processed' and may not be described as 'Green Fresh' or 'Garden Produce'. It shall be clearly marked as prepared from dried raw material.
- 4. Dehydrated any dry fruits; if canned, shall be clearly marked as prepared from dried raw material.
- 5. When dry fruit is used for making jam or cheese, it shall be clearly declared so on the label.
- 6. Jelly made from sugar and chemical pectin shall be clearly declared as
- 7. When preserves are packed in sanitary top cans, the contents shall not be less than 85 per cent of the total space of the can.
- 8. In case of fruit chutney, the names of fruits may not be declared on the label. However, in case of mango chutney or other chutneys the content shall be declared on the label.
- 9. In case of tomato puree and paste the percentage of total soluble solids shall be declared on the label.
- 10. In case of sauces other than tomato and soybean, the names of fruits, vegetables or dried fruits used shall be declared on the label.
- 11. When more than one vegetable is used in vinegar pickle the product shall be labeled as mixed pickles.
- 12. In case of oil pickles the name of the fruit or vegetable used shall be

EXERCISES

- Q.1. What are different standards laid down by statutory bodies ?
- Q.2. What is food adulteration? Explain in brief.



OBJECTIVES - Fill in the blanks.

- Conditioning grain by removing moisture to equilibrium level with normal atmospheric air in order to preserve its quality and nutritive value is called.....
- Moisture content of paddy during harvesting is
- Moisture content of paddy for storage is
- is used for drying small quantity of grain with 450c of air temperature and 4m3/min airflow.
-dryer is most popular dryer in India.
- Grain temperature in LSU dryer during drying should be less than 6. or equal to
- Moisture content of substance is generally expressed in percent
- The top sieve of the screening device is called as 8.
- Early harvest followed by drying gives the best milling recovery.
- Drying in the bin is called drying. 10.
- Moisture content of grain is measured by 11.
- In deep bed drying air passed through the grain layer should be 12. more than depth.
- In thin layer drying the grain bed depth should not exceed 13.
- The post harvest losses are estimated to be about 14.
- Rice should be harvested......after flowering. 15.
- Sorghum should be harvested.....after flowering. 16.
- Sugarcane should be harvested when the ratio of brix between top 17. and bottom part of cane is nearly.....
- Moisture content for safe storage is.....for most of the 18. crops.
- Hay making involves two processes namely..... 19.
- The process of making silage is called..... 20.

21. Circulation of relatively dry air arc called	n of fruits and vegetables
 23	- '0
 23	- '0
fish, packaged meant and some cold packe 25	il-ullilorm drying
 25	1000:
 Ine upper edge of the drying zone at the interior is called the	
 27. The normal air temperature recommended is	erface with the wet zone
 29. The best silage is made form	by batch or bin drying
30. Total heat content of the drying is called	
content of the drying is called	
21 ary mg is called	crops.
31. Milk powder is prepared by drying the mi	lk in spray dryer by the
32. For highly heat sensitive foods,	
33. In twin dryer, rotations of the	
place in produce on the basis of	to each other. difference in size takes
35. In hammer mill, size ready-art	
 35. In hammer mill, size reeducation of slid is a 36. Specific heat andare two important in heat processing operation. 37. In 	due to thermal properties used
37. In Separation.	ater than gravitational
acceleration would lift the particle. 38. Loss of liquid in the particle.	9
38. Loss of liquid in thawing is called	
40. Air screen cleaner separates the seed	ng to the difference in
41. The broken rice is separated with the help of	ng to the difference in

In processing plant, precleaning is done by...... Stratification and separation are the steps of operation in separator. In pneumatic conveyor, the terminal velocity of grain should bethat air velocity. Cylindrical disc separator separates the material on the basis of Burr/plate mills are commercially used for The Separator separates the material on the basis of relative rolling ability of material.refers to circulate a small amount of air through the grain to cool and ventilate the grain at frequent intervals More than.....times carotene is preserved through artificial drying than sun drying. Thebasis moisture content is used mainly by research workers. The moisture content on dry basis is alwaysthan wet basis. Equilibrium moisture content is zero atrelative humidity. Aqueous or slat solution of different concentration is used to control.....of air. Removal of foreign or dissimilar material is called 54. Classification of material on the basis of commercial value of usage 55. is called Round hole screens are recommended for cleaning and sorting of 56.material. Screen cleaners that employ an air blast to assist in cleaning is called 57. Cream separator uses centrifugal force for separation with bowlmills. 58. speed......rpm.is the trade term used relative to the reduction of grain in to 59. meal or flour.indicates the uniformity of grain in resultant product.

61.	Themills are commercially used in preparation of feed and	Ate
62.	method measures silage density in an upright silo by	82.
63.	Baffle and I SII are	83
54.	Baffle and LSU areflow mixing dryer.	84
55.		85
	rate period.	86
6.	dryers are used for fruit and vegetables.	8
7.	Drying involves both	
3.	Drying involves bothandtransfer. All commercial flow dryers are designed ondrying	8
•	principle. designed ondrying	8
9.	In general, an air temperature ofis recommended for deep	9
	drying. drying. is recommended for deep	9
).	drying is used for drying the parboiled grain.	
١.	air drying is used 6	
		9
	grain. are greatly used for the storage of 25 to 500 tonnes of	ю
	The chemical used 6	
l.	The chemical used for determination of specific gravity of granular agricultural materials is	
		н
5.	In thin layer drying generally the size reduction.	ш
_	In thin layer drying, generally thickness of grain bed is taken asonly.	н
6.	is the dimensionless ratio.	н
7.	AND THE RESERVE OF THE PARTY OF	ш
_	wet bulb temperature of atmosphere.	П
8.	in d	п
	residue left is liquid.	н
9.	······································	ш
	to major diameter.	п
0.	·······	
31.	Parboiled rice takestime for cooking for same degree of	
	softnesstime for cooking for same degree of	П

82.	Membrane separation is also referred to as
83.	means individual quick blanching.
84.	In spray drying the drying time varies from
85.	Cyclone separaters work on principles ofandforce.
86.	The oil treatment is given to the pulses inmilling.
87.	Red earth treatment to the pulse is given inmilling method.
88.	The absorbent or dehydrating agent likeor activated alumina is used for reducing vapour pressure of the drying air.
89.	is the science to determination of flow.
90.	means removing field heat.
91.	Forced air pre-cooling is done at
92.	is the most rapid method of pre-cooling used for leafy vegetables.
93.	Use of beta or gamma treatment is commonly calledpasteurization.
94.	RPEC dryer was developed at
95	The most common tuning.
96 97	
98	
10000	Scalper is used for separation.
500	00. In ball mill, the size reduction is done by
100	ot a una la talla generally
	02. Extraction of soluble constituents from a solid by using solvent is
	is recommended, if the RH is below
100	105is the separation of solid from figure by passing the first mixture through fine pores.
	106. 1 atmosphere = 107. Overall thermal efficiency of drum dryer ranges from

108.	Overall thermal efficiency of spray dryer ranges from
109.	In drum dryer, the drums usually rotate in
110.	Most commercial chiller operates at higher temperature upto
111.	Fat globules in normal milk are ofmicrons in size.
112.	are used in canning of vegetables.
113.	heat exchanger is very popular in diary industry.
114.	The acidity of milk is due toacid.
115.	Reverse osmosis is also known as
116.	The instrument used for humidity measurement is called
117.	hours of bright sunshine during the course of the day.
118.	The most recent addition of greenhouse film plastic covering isfilm.
119.	is the best method for preservation of meat and fish for a longer time.
120.	type of green house is constructed on hilly terrain.
121.	The diameter of pit silo is usually limited toand its depth is kepttimes that of the diameter.
122.	Pyranometer is also known
	* - ex in the second

ANSWERS

1 dr	ying	2	23 to 25%
	2 to 14%	4	Sack dryer
,	.SU	6	400C
	et basis	8	Scalper
	echanical	10	Deep bed
1	ielectric meters	12	20cm
	Ocm	14	25%
DESCRIPTION OF THE PARTY OF THE	2 days	16	40 days
	ne	18	14%
	lrying and curing	20	Ensiling
	diabatic	22	Solar cabinet
	sun drying	24	Sharp freezing
	oatch	26	Drting front
~	50C to 500C	28	Continuous
	naize and sorghum	30	Enthalpy
2000	ublimation	32	Freeze
	pposite	34	Screen cleaner
	impact and crushing	36	Thermal conductivity
	pneumatic	38	Drip-loss
	grain length	40	Size, shape
	lisc	42	Screening
	gravity	44	Less
	Grain length	46	Grinding
	spiral	48	Aeration
49	five	50	Dry
51	larger	52	Dry
53	relative humidity	54	Cleaning
55	grading	56	Spherical
	fanning	58	8000
	milling	60	Fineness modulus
61	attrition/burr/plate	62	Radiation
63	continuous	64	Convection

65	falling	66	Tray
67	heat, mass	68	Thin layer
69	400 to 440C	70	Conduction
71	natural	72	Bag structures
73	toluene	74	Rittinger and Kick's
75	20 cm	76	Specific gravity
77	A sling psychrometer	78	Evaporation
79	sphericity	80	Gerber
81	more	82	Cold sterilization process
83	IQB	84	5 to 10 sec
85	Centrifugal, gravitational	86	Dry
87	wet	88	Calcium chloride
89	rheology	90	Pre cooling
91	170C	92	Vacuum cooling
93	Non-thermal	94	IIT, Kharagpur
95	EDCT mixture or EDP tablets	96	Physic-thermal
97	a cyclone	98	Less than 2
99	rough	100	Impact
101	viscoelastic	102	Distillation
103	70%	104	LSU
105	Filtration	106	100 kp
107	35 to 80%	108	20 to 50%
109	opposite direction	110	10 to 120C
111	1 to 15	112	brines
113	plate	114	DAY THE SECOND CONTRACTOR OF THE SECOND CONTRA
115	hyper filtration	116	Lactic
117	sunshine recorder	118	Hygrometer
119	Freezing		Tefzel t2
121	6 m, 2 to 3	120	Uneven span
		122	solarimeter

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Questions from Theory Examination (2009 to 2011)

- Q.1. a) What is greenhouse? Explain the advantages of greenhouse.
 - b) Give the classification of greenhouse on the basis of construction and covering material.
- Q.2. What are the different irrigation systems in greenhouse? Explain drip irrigation system in detail.
- Q.3. Enlist and discuss in brief the different methods of greenhouse cooling.
- Q.4. a) State the importance of drying.
 - b) Explain the features of mechanical drying.
- Q.5. a) Enlist different types of storage structures for food grains.
 - b) Explain kothar type storage structure with neat sketch.
- Q.6. a) Enlist the different types of separators.
 - b) Explain inclined draper belt separator with neat sketch.
- Q.7. What is drying? Give the importance of drying.
- Q.8. What is seed processing? Give general sequence of seed processing operations.
- Q.9. Define cleaning. Explain in shoort the vibratory air screen cleaner.
- Q.10. Enumerate the properties of an ideal greenhouse covering material.
- Q.11. Enlist the properties of growth media.
- Q.12. Explain in short the inclined belt draper.
- Q.13. Write short notes on (Any two):
 - 1) Covering materials for greenhouse.
 - 2) Hammer mill
 - 3) Grading of vegetables

Define the following terms:

1) Drying

- 2) Grading
- 3) Relative humidity

- 4) Greenhouse effect
- 5) Cleaning
- 6) Greenhouse

- 7) Ventilation
- 8) Food adulteration

Fill in the blanks:

- 1) When small, isolated cultural area is required then type of greenhouse is used.
- 2) The light intensity is measured by the international unit known as
- 3) The capacity of Bukhari type storage structure varies from to tones.
- 4) Spiral separator separates the grain as per their
- 5) In mill, the grain size is reduced by shearforce.
- 6) The mark on any article of food is a guaranty of Bureau of Indian Standards for that commodity.
- The Lousiana State University dryer is a continuous flowtype of dryer.
- 8) For most crops, the acceptable range of relative humidity in greenhouse is between to percent.

State true or false:

- 1) The most widely used glass for green house is the float glass.
- 2) C:N ratio and bulk density are properties of root medium.
- 3) Sorting refers to the removal of few large particles in an initial process.
- 4) Roller grader is suitable for spherical fruits.
- The specific gravity separator makes the separation according to difference in length of the material.

