ARULMIGU PALANI ANDAVAR ARTS COLLEGE FOR WOMEN, PALANI

PG DEPARTMENT OF BOTANY

LEARNING RESOURCES

BOTANY FOR ENTREPRENEURSHIP DEVELOPMENT

Biogas, naturally occurring gas that is generated by the breakdown of organic matter by anaerobic bacteria and is used in energy production. Biogas differs from natural gas in that it is a renewable energy source produced biologically through anaerobic digestion rather than a fossil fuel produced by geological processes. Biogas is primarily composed of methane gas, carbon dioxide, and trace amounts of nitrogen, hydrogen, and carbon monoxide. It occurs naturally in compost heaps, as swamp gas, and as a result of enteric fermentation in cattle and other ruminants. Biogas can also be produced in anaerobic digesters from plant or animal waste or collected from landfills. It is burned to generate heat or used in combustion engines to produce electricity.

The use of biogas is a green technology with environmental benefits. Biogas technology enables the effective use of accumulated animal waste from food production and of municipal solid waste from urbanization. The conversion of organic waste into biogas reduces production of the greenhouse gas methane, as efficient combustion replaces methane with carbon dioxide. Given that methane is nearly 21 times more effective in trapping heat in the atmosphere than carbon dioxide, biogas combustion results in a net reduction in greenhouse gas emissions. Additionally, biogas production on farms can reduce the odours, insects, and pathogens associated with traditional manure stockpiles.

Animal and plant wastes can be used to produce biogas. They are processed in anaerobic digesters as a liquid or as a slurry mixed with water. Anaerobic digesters are generally composed of a feedstock source holder, a digestion tank, a biogas recovery unit, and heat exchangers to maintain the temperature necessary for bacterial digestion. Small-scale household digesters containing as little as 757 litres (200 gallons) can be used to provide cooking fuel or electric lighting in rural homes. Millions of homes in less-developed regions, including China and parts of Africa, are estimated to use household digesters as a renewable energy source.

Large-scale farm digesters store liquid or slurried manure from farm animals. The primary types of farm digesters are covered lagoon digesters, complete mix digesters for slurry manure, plug-flow digesters for dairy manure, and dry digesters for slurry manure and crop residues. Heat is usually required in digesters to maintain a constant temperature of about 35 °C (95 °F) for bacteria to decompose the organic material into gas. An efficient digester may produce 200–400 cubic metres (7,000–14,000 cubic feet) of biogas containing 50–75 percent methane per dry ton of input waste.

The natural decomposition of organic matter in a landfill occurs over many years, and the biogas produced (also known as landfill gas) can be collected from a series of interconnected pipes located at various depths across the landfill. The composition of this gas changes over the life span of the landfill. Generally, after one year, the gas is composed of about 60 percent methane and 40 percent carbon dioxide. Landfill collection varies according to the percentage of organic waste and the age of the facility, the average energy potential being about 2 gigajoules (1,895,634 BTU) per ton of waste.

Landfill gas collection systems are increasingly being implemented to prevent explosions from methane accumulation inside the landfill or to prevent the loss of methane, a greenhouse gas, into the atmosphere. The collected gas can be burned at or near the site in furnaces or boilers, but it is instead often used in internal combustion engines or gas turbines to create electricity, given the limited need for heat production at most remote landfill locations.

THE METHANE GENERATION PROCESS

Methane generation is accomplished by anaerobic digestion (biological oxidation in the absence of oxygen) of organic substances such as livestock waste and plant refuse. The gas produced in an on-farm digester is only about 65 percent methane, the rest being carbon dioxide and trace organic gases.

Methane generation requires two main groups of anaerobic bacteria-the `acid formers', which convert waste to organic acids; and the `methane formers', which then convert these organic acids to methane and carbon dioxide (Figure 1). Also, there are two distinct temperature ranges in which these bacteria can produce significant amounts of methane gas-the mesophillic range (90-110F)and the thermophillic range (120-140F). Recent research using thermophillic bacteria shows some promise and will be discussed briefly later; however, this publication deals mainly with conventional digestion units operated in the mesophillic range.

Methane generation is much like the controlled combustion (incomplete burning) of wood to produce charcoal-i.e., burning a substance in an air-limited environment to produce a more readily usable, yet high-energy end-product. The combustion of charcoal requires oxygen to be completed and produces heat, ash, water vapor and carbon dioxide. The combustion of methane also requires oxygen to burn producing heat, water vapor and carbon dioxide.

METHANE FROM LIVESTOCK WASTE--POTENTIAL AND PROBLEMS

Production potential. Methane production is usually expressed in terms of cubic feet of gas generated per pound of volatile solids destroyed. Volatile solids are the organic portion of livestock waste; about 80 percent of the manure solids are volatile. A gallon of liquid manure containing 8 percent solids potentially can provide about 3 3/4 cubic feet of digester gas, or 2 1/2 cubic feet of methane (Roughly 10-13 cubic feet of gas can be produced per pound of volatile solids destroyed in a properly-operating digester. Since about half of the volatile solids added can be destroyed and half to three-fourths of the gas produced will be methane, about 5 cubic feet of digester gas (3 cubic feet of methane) can be produced per pound of total manure solids added).

In terms of digester size, it is possible to produce 3/4 to 2 1/2 cubic feet of gas (1/2 to 1 1/2 cubic feet of methane) per cubic foot of digester volume. The gas production expected from various livestock species is shown in Table 1.

Table 1. Daily Waste and Methane Production by Dairy, Beef and Swine per 1000 Pounds of Animal Weight.

Item	Dairy	Beef	Swine
Raw manure (lb.)	82.0	60.0	65.0
Total solids (lb.)	10.4	6.9	6.0
Volatile solids (lb.)	8.6	5.9	4.8
Methane potential (cu.ft.)*	28.4	19.4	18.6

* Based on 65 percent of gas being methane.

Toxic components in waste. Several substances commonly found in livestock waste can inhibit methane production if present in large enough concentrations. The most common is ammonia because it is present in large quantities in animal urine. An ammonia concentration of 1500 parts per million (ppm) is considered the maximum allowable for good methane production (Table 2). Above that level, the waste should be diluted with water.

Table 2. Effect of Ammonia Concentration on Methane Production.

Concentration (mg/l of Ammonia-N)	Effect
5 - 200	Beneficial
200 - 1000	No adverse effect
1500 - 3000	Possible inhibition at higher pH Values
Above 3000	Toxic

Certainly, large quantities of antibiotics and cleaning disinfectants should be kept out of the digester. For this reason, consider excluding farrowing building waste from the digester. The antibiotic rumensin is also toxic to methane bacteria and should not be fed to cattle whose waste is to be used for methane generation.

Value of adding crop residues. The primary limitation on livestock waste loading rates is the high nitrogen (N) content compared to its carbon (C) content. The ratio of carbon to nitrogen in that waste added to the digester should be 20 parts C to one part N for optimum methane production.

Crop residues and leaves, which are usually low in nitrogen content but high in carbon, could be useful in improving digester performance. Mixing crop residue with high nitrogen livestock waste provides a more favorable C:N ratio; and gas production should increase accordingly.

DIGESTER GAS VALUE AND USES

Energy Value of the Gas

If we know the potential for methane production from various livestock species and the cost of comparable amounts of commercial fuel, we can then determine the value of digester gas. Assuming digester gas has an energy value of 650 British Thermal Units (BTUs) per cubic foot and a gallon of propane fuel, with an energy value of 91,700 BTUs, costs 60 cents (1980 price), it takes about 235 cubic feet of digester gas to equal one dollar's worth of propane. Table 3 estimates the value of the potential gas production from each livestock type.

Unfortunately, up to 1% of this gas must be used to heat the manure that is put into the digester. In addition, some heat is needed to keep the digester warm during winter months.

Uses for the Gas

Digester gas can be used wherever natural gas is applicable. Digester gas requirements for household activities were computed at Pennsylvania State University (Table 4). On the farm, it can be used for grain dryers or to operate gas water heaters, which provide heat back to the digester and floor heat for nearby livestock buildings. It can also be burned in a commercial space heater.

BIOGAS

Biogas is a renewable energy source produced by the breakdown of organic matter by certain bacteria under anaerobic conditions. It is a mixture of methane, hydrogen, and carbon dioxide. It can be produced by agricultural waste, food waste, animal dung, manure, and sewage. The process of biogas production is also known as anaerobic digestion.

Biogas recycles the waste products naturally and converts them into useful energy, thereby, preventing any pollution caused by the waste in the landfills, and cutting down the effect of the toxic chemicals released from the sewage treatment plants.

Biogas converts the harmful methane gas produced during decomposition, into less harmful carbon dioxide gas.

The organic material decomposes only in a wet environment. The organic matter or the waste dissolves in water and forms a sludge which is rich in nutrients and used as a fertilizer.

Biogas Plant

The biogas production is carried out in anaerobic digesters known as Biogas plant. These have five components:

- An inlet to feed the slurry
- The fermentation chamber where the biogas is produced with the activity of microorganisms,
- The gas storage tank to store the gas produced,
- The outlet for the used slurry,
- The exit pipe for removing the gas produced.

The organic matter if fed into the digesters which are completely submerged in water to provide it with an anaerobic environment. These digesters are hence called anaerobic digesters. The microorganisms breakdown the organic matter and convert it into biogas.

The biogas thus produced is supplied to the respective places through the exit pipes.

Breakdown of Organic matter

1. The first stage involves the breakdown of organic polymers, such as carbohydrates, making it available to the next stage of bacteria known as the acidogenic bacteria.
2. The acidogenic bacteria then convert the sugar and amino acids into carbon dioxide, ammonia, hydrogen, and organic acids.
3. The organic acids are now converted into acetic acid, hydrogen, ammonia, and carbon dioxide.
4. These are finally converted into methane and carbon dioxide by the action of methanogens.

Methane is a combustible gas, i.e., it can be burnt. This gas is supplied to various places and is used in cooking and lighting. It is an eco-friendly gas and reduces various environmental problems like, it reduces the reliance on fossil fuels.

Introduction to Biogas Technology

Biogas It's a mixture of gas produced by the microorganisms during the anaerobic fermentation of biodegradable materials. Anaerobic fermentation is a biochemical process in which particular kinds of bacteria digest biomass in an oxygen-free environment resulting in production of CH_4, CO_2, H_2 and traces of other gases along with decomposed mass.

Properties of Biogas

Biogas is a mixture of different components and the composition varies depending upon the characteristics of feed materials, amount of degradation, etc. Biogas predominantly consists of 50 to 70 per cent methane, 30 to 40 per cent carbon dioxide and low amount of other gases. Methane is a combustible gas. The energy content of biogas depends on the amount of methane it contains. Methane content varies from about 50 percent to 70 percent.

Microbiology of biogas production

The production of biogas from organic material under anaerobic condition involves sequence of microbial reactions. During the process complex organic molecule present in the biomass are broken down to sugar, alcohols, pesticides and amino acids by acid producing bacteria. The resultant products are then used to produce methane by another category of bacteria.

The biogas production process involves three stages namely:

i. Hydrolysis
ii. ii. Acid formation and
iii. iii. Methane formation

The process of degradation of organic material in every step is done by range of bacteria, which are specialized in reduction of intermediate products formed. The different process involved in production of biogas is given in the figure. The efficiency of the digestion depends how far the digestion happens in these three stages. Better the digestion, shorter the retention time and efficient gas production.

Hydrolysis

The complex organic molecules like fats, starches and proteins which are water insoluble contained in cellulosic biomass are broken down into simple compounds with the help of enzymes secreted by bacteria. This stage is also known as polymer breakdown stage (polymer to monomer). The major end product is glucose which is a simple product.

Acid formation

The resultant product (monomers) obtained in hydrolysis stage serve as input for acid formation stage bacteria. Products produced in previous stage are fermented under anaerobic conditions to form different acids. The major products produced at the end of this stage are acetic acid, propionic acid, butyric acid and ethanol.

Methane formation

The acetic acid produced in the previous stages is converted into methane and carbon dioxide by a group of microorganism called "Methanogens". In other words, it is process of production of methane by methanogens. They are obligatory anaerobic and very sensitive to environmental changes. Methanogens utilise the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water. It is these components that make up the majority of the biogas emitted from the system. Methanogenesis is sensitive to both high and low pH's and occurs between pH 6.5 and pH 8. Major reactions occurring in this stage is given below:

$CH_3COOH \Rightarrow CH_4 + CO_2$

Acetic acid   Methane   Carbon dioxide

$2CH_3CH_2OH + CO_2 \Rightarrow CH_4 + 2CH_3COOH$

Ethanol   Carbon dioxide   Methane   Acetic acid

$CO_2 + 4H_2 \Rightarrow CH_4 + 2H_2O$

Carbon dioxide Hydrogen   Methane   Water

Biogas plant and its components:

A physical structure designed to carry out anaerobic digestion of organic materials is called "Biogas plant". Following are the components of biogas plants:

Mixing tank : Cow dung is collected from the shed and mixed with the water in equal proportion (1:1) to make a homogenous mixture (slurry) in the mixing tank

Feed inlet pipe/tank : The homogenous slurry is let into the digester through this inlet pipe (KVIC biogas plants)/tank (Janatha biogas plants)

Digester : The fed slurry is subjected to anaerobic fermentation with the help of microorganisms inside the digester.

Gas holder : As a result of anaerobic fermentation, gas produced is stored in gas holder (Drum in the case of KVIC and in dome in the case of fixed dome biogas plants)

Slurry outlet tank/pipe : The digested slurry is let out from the digester through slurry outlet pipe (KVIC biogas plants)/tank (Janatha biogas plants)

Gas outlet pipe : Stored gas is released and conveyed through the gas outlet pipe present at the top of gas holder.

Classification of biogas plants Based on the nature of feeding, biogas plants would be broadly divided into 3 types and they are as follows;

i. Batch type: The organic waste materials to be digested under anaerobic condition are charged only once into a reactor-digester. The feeding is between intervals, the plant is emptied once the process of digestion is complete. Retention time usually varies from 30 to 50 days. The gas production in it is intermittent. These plants are well suited for fibrous materials. This type of plant needs addition of fermented slurry to start the digestion process and it not economical to maintain which are considered to be the major draw backs.

ii. ii. Semi continuous: A predetermined quantity of feed material mixed with water is charged into the digester from one side at specified interval of time; (say once a day) and the digested material (effluent) equivalent to the volume of the feed, flows out of the digester from the other side (outlet).

iii. iii. Continuous type: The feed material is continuously charged to the digester with simultaneous discharge of the digested material (effluent). The main features of this type of plants are continuous gas production, requires small digestion area, lesser period for digestion, less maintenance, etc.

The biogas plants used in the villages are of semi continuous type employing animal dung and other biomass as the feed stock for biogas production. So the classification of semi-continuous type biogas plant is explained below.

i. Floating drum type – KVIC model

ii. ii. Fixed dome type model – Deenbandhu model

Floating drum type (Constant pressure)

In this type of plants digester is made of bricks and is of circular in shape. It is constructed typically underground to lessen the heat loss from the plant. Partition wall is constructed (dividing the digester into two parts) for higher size capacity plants to avoid the short-circuiting of digested slurry with the fresh feed. Separate gasholder is fabricated and fixed to store the gas produced during digestion besides acting as an anaerobic seal for the process. As the volume of gas production increases drum starts to rise and if the stored gas is withdrawn the level of drum drops to lower level. Scum formed in the digester can be broken with the help of drum rotation both clockwise and anticlockwise. Central guide frame is provided to hold the gasholder and to allow it to move vertically during gas production. The drum is made up of mild steel and it constitutes around 60 per cent of overall plant costs. Salient features of this type of plants include weight of drum helps to discharge the gas produced at constant pressure, volume of gas storage can be judged visually.

Small masonry tanks are constructed for mixing of cow dung, water and to discharge the slurry out of the digester. Concrete pipes are provided to convey the raw and digested slurry in and out of the digester. Gas outlet pipe is provided at top of the drum to let the gas out of drum. KVIC floating drum model is predominantly used in India and fig shows the schematic diagram of it.

Advantages and disadvantages of floating drum plant.

Advantages:

i. Higher gas production per cum of the digester volume is achieved.

ii. ii. Floating drum has welded braces, which help in breaking the scum by rotation.

iii. iii. No problem of gas leakage.

iv. iv. Constant gas pressure.

Disadvantages

i. It has higher cost, as cost is dependent on steel and cement

ii. ii. Heat is lost through the metal gasholder.

iii. iii. Gasholder required painting once or twice a year, depending on the humidity of the location.

iv. iv. Flexible pipe joining the gasholder to the main gas pipe requires maintenance, as ultraviolet rays in the sun damage it.

FIXED DOME BIOGAS PLANTS (Constant volume)

To reduce the cost of biogas plants, researchers has designed fixed dome plants in which dome act as gasholder in place of high cost drum. Gasholder and digester constructed as single unit. The digesters of such plants are completely underground to maintain a perfect environment for anaerobic fermentation to take place besides avoiding cracking of dome due to difference in temperature and moisture.

JANATHA BIOGAS PLANTS

Developed exclusively in India completely masonry structure. Provision of Inlet and outlet of raw and digested slurry is constructed in the form of tank. Slurry fed is allowed to undergo anaerobic fermentation in the digester. Gas produced as a result rises up and gets collected in the dome. As the pressure of gas stored in the dome increases, it pushes up the slurry down and causes the slurry level to increase both in inlet and outlet tanks. These levels drop down when the gas in the dome is used up. This displacement provides necessary pressure to push the gas up to the usage point. The pressure coming out of the dome is of variable type as constant in the case of floating drum type. Volume of gas stored in the plant is equal to the total volume of slurry displaced both in inlet and outlet tanks.

DEENBANDHU BIOGAS PLANTS

One of the outstanding designs of biogas plants in Indian biogas development program is Deenbandhu biogas plant design. It is improved version of Janatha biogas plant model. Action for food production (AFPRO), a voluntary organization based in New Delhi, developed this model in 1984. This is constructed with locally available materials and the plant demand skillful manpower for construction. Important considerations for design modification are reduction in the overall construction cost, elimination of the loss of biogas through inlet chamber and maximum utilization of digester volume to make the operational HRT close to the designed HRT.

It is constructed by joining the two spheres of different diameters at their bases, thus reducing the cost of bricks used in construction of digester wall. Bottom part of the plant is a designed as a segment of sphere, whereas the top portion as hemisphere. In this plant feedstock is fed through concrete pipes and the digested slurry is taken out the digester through tank. As a precaution to avoid the entry of slurry through gas outlet pipe, outlet opening is constructed 150 mm lower than the bottom of gas outlet pipe. Gas holding capacity is 33 per cent of total capacity of the plant. Studies proved that the cost of deenbandhu is 30 and 45 per cent less than that of Janatha and KVIC biogas plants. Fig shows the schematic diagram of deenbandhu biogas plant model.

Advantages

i. It has low cost compare to floating drum type, as it uses only cement and no steel.
ii. It has non-corrosion trouble.
iii. It this type heat insulation is better as construction is beneath the ground.
iv. Temperature will be constant.
v. Cattle and human excreta and long fibrous stalks can be fed.
vi. No maintenance.

Disadvantages:

i. This type of plant needs the services of skilled masons, who are rather scarce in rural areas.
ii. Gas production per cum of the digester volume is also less.
iii. Scum formation is a problem as no stirring arrangement
iv. It has variable gas pressure

FACTORS INVOLVED IN BIOGAS PRODUCTION

Biogas production involves different physical, chemical and biological process for conversion of biodegradable organic materials to energy rich gas.

C/N ratio

The ratio of carbon to nitrogen present in the feed material is called C:N ratio. It is a crucial factor in maintaining perfect environment for digestion. Carbon is used for energy and nitrogen for building the cell structure. Optimum condition for anaerobic digestion to take place ranges from 20 to 30:1. This means the bacteria use up carbon about 20 to 30 times faster than they use up nitrogen.

When there is too much carbon in the raw wastes, nitrogen will be used up first and carbon left over. This will make the digestion slow down and eventually stops. On the other hand if there is too much nitrogen, the carbon soon becomes exhausted and fermentation stops. The nitrogen left over will combine with hydrogen to form ammonia. This can kill or inhibit the growth of bacteria specially the methane producers.

Temperature

Temperature affects the rate of reaction happening inside the digester. Increase in the ambient temperature increases the rate of reaction thus increasing the biogas production as well. Methane bacteria work best at a temperature of 350 – 380 C. The fall in gas production starts at 200C and stops at a temperature of 10 0C. Studies howed that 2.25 m 3 of gas was produced from 4.25m3 of cattle dung everyday when the digester temperature was 250C. When the temperature rose to 28.30C the gas production was increased by 50 per cent to 3.75 m 3 per day.

Retention time

It is the theoretical time that particular volume of feedstock remains in the digester. In other words, retention time describes the length of time the material is subjected to the anaerobic reaction. It is calculated as the volume of digester divided by the feedstock added per day and it is expressed in days. Under anaerobic condition, the decomposition of the organic substances is slow and hence need to keep for long time to complete the digestion. In case of Indian digesters, where the feed stock is diluted with equal composition, so demarcation prevails between solid and liquid. In this case, biomass in the form of bacteria is washed out; hence the solid retention time (SRT) is equal to hydraulic retention time (HRT).

Loading rate

Loading rate is defined as the amount of raw material fed to the digester per day per unit volume. If the reactor is overloaded, acid accumulation will be more obviously affecting daily gas production. On the other hand, under loading of digester have negative impact in designed gas production.

Toxicity

Though small quantities of mineral ions like sodium, potassium stimulates the growth of bacteria, the high concentration of heavy metals and detergents have negative impact in gas production rate. Detergents like soap, antibiotics, and organic solvents are toxic to the growth of microbes inside the digester. Addition of these substances along with the feed stock should be avoided.

pH or hydrogen ion concentration

To maintain a constant supply of gas, it is necessary to maintain a suitable pH range in the digester. pH of the slurry changes at various stages of the digestion. In the initial acid formation stage in the fermentation process, the pH is around 6 or less and much of CO_2 is given off. In the latter 2-3 weeks times, the pH increase as the volatile acid and N_2 compounds are digested and CH_4 is produced. The digester is usually buffered if the pH is maintained between 6.5 and 7.5. In this pH range, the micro – organisms will be very active and digestion will be very efficient. If the pH range is between 4 and 6 it is called acidic. If it is between 9 and 10 it is called alkaline. Both these are detrimental to the methanogenic (Methane production) organisms.

Total solid content

The raw cow dung contains 80-82% of moisture. The balance 18-20% is termed as total solids. The cow dung is mixed usually in the proportion of 1:1 in order to bring the total solid content to 8-10%. This adjustment of total solid content helps in digesting the materials at the faster rate and also in deciding the mixing of the various crop residues as feed stocks in biogas digester.

Feed rate

One of the prerequisites of good digestion is the uniform feeding of the digester so that the micro – organisms are kept in a relatively constant organic solids concentration at all times. Therefore the digester must be fed at the same time everyday with a balanced feed on the same quality and quantity.

Diameter to depth ratio

Studies reveal that gas production per unit volume of digester capacity was maximum, when the diameter to depth ratio was in the range of 0.66 to 1.00. One reason may be that because in a simple unstirred single stage digester the temperature varies at different depths. The most activity digesting sludge is in the lower half of the digester and this is less affected by changes in night and day temperature.

Nutrients

The major nutrients required by the bacteria in the digester are, C, H_2, O_2, N_2, P and S, of these nutrients N_2 and P are always in short supply and therefore to maintain proper balance of nutrients an extra raw material rich in phosphorus (night soil, chopped leguminous plants) should be added along with the cow dung to obtain maximum production of gas.

Degree of mixing

Bacteria in the digester have very limited reach to their food, it is necessary that the slurry is properly mixed and bacteria get their food supply. It is found that slight mixing improves the fermentation, however a violent slurry agitation retards the digestion.

Type of feed stocks

All plant and animal wastes may be used as the feed materials for a digester. When feed stock is woody or contains more of lignin, then digestion becomes difficult. To obtain as efficient digestion, these feed stocks are combined in proportions. Pre-digestion and finely chopping will be helpful in the case of some materials. Animal wastes are predigested. Plant wastes do not need pre-digestion. Excessive plant material may choke the digester.

USES OF BIOGAS

Biogas serves as a suitable alternate fuel for satisfying the energy needs of human society. It can be used for production of power, for cooking, lighting, etc. Figure explains the flow chart of different applications of biogas.

Cooking and lighting

The primary domestic uses of biogas are cooking and lighting. Because biogas has different properties from other commonly used gases, such as propane and butane, and is only available at low pressures (4 - 8 cm water), stoves capable of burning biogas efficiently must be specially designed. Biogas burns with blue flame and without any soot and odour which is considered to be one of the major advantage compared to traditional cooking fuel like firewood and cow dung cake.

Lighting can be provided by means of a gas mantle, or by generating electricity. Biogas mantle lamps consume 2-3 cft per hour having illumination capacity equivalent to 40 W electric bulbs at 220 volts. This application is predominant in rural and unelectrified areas.

Biogas as an Engine Fuel

Biogas can be used as a fuel in stationary and mobile engines, to supply motive power, pump water, drive machinery (e.g., threshers, grinders) or generate electricity. It can be used to operate four stroke diesel and spark ignition engines. Electricity generation using biogas is a commercially available and proven technology. Typical installations use spark-ignited propane engines that have been modified to operate on biogas. Biogas-fueled engines could also be used for other on-farm applications. As discussed below, diesel or gasoline engines can be modified to use biogas.

IC engines (typically used for electricity generation) can be converted to burn treated biogas by modifying carburetion to accommodate the lower volumetric heating value of the biogas into the engine and by adjusting the timing on the spark to accommodate the slower flame velocity of biogas ignition systems. When biogas is used to fuel such engines, it may be necessary to reduce the hydrogen sulphide content if it is more than 2 percent otherwise the presence will lead to corrosion of engine parts.

In terms of electricity production, small internal combustion engines with generator can be used to produce electricity in the rural areas with clustered dwellings thus promoting decentralized form of electricity avoiding grid losses.

Use of biogas as vehicular fuel

Biogas is suitable as a fuel for most purposes, without processing. If it is to be used to power vehicles, however, the presence of CO_2 is unsatisfactory, for a number of reasons. It lowers the power output from the engine, takes up space in the storage cylinders (thereby reducing the range of the vehicle), and it can cause problems of freezing at valves and metering points, where the compressed gas expands, during running, refuelling, as well as in the compression and storage procedure. All, or most, of the CO_2 must therefore be removed from the raw biogas, to prepare it for use as fuel for vehicles, in addition to the compression of the gas into high-pressure cylinders, carried by the vehicle.

Uses of biodigested slurry

The slurry after the digestion will be washed out of the digester which is rich in various plant nutrients such as nitrogen, phosphorous and potash. Well-fermented biogas slurry improves the physical, chemical and biological properties of the soil resulting qualitative as well as quantitative yield of food crops. Slurry from the biogas plant is more than a soil conditioner, which builds good soil texture, provides and releases plant nutrients. Since there are no more parasites and pathogens in the slurry, it is highly recommended for use in farming. The economic value of the slurry shows that investment can be gained back in three to four year's time if slurry is properly used.

The cow dung slurry after digestion inside the digester comes out with following characteristics and has following advantages:

- When fully digested, effluent is odourless and does not attract insects or flies in the open condition.
- The effluent repels termites whereas raw dung attracts them and they can harm plants fertilised with farmyard manure (FYM).
- Effluent used as fertiliser reduces weed growth with about 50%. When FYM is used the undigested weed seeds cause an increased weed growth.
- It has a greater fertilising value than FYM or fresh dung. The form in which nitrogen available can be easily assimilated by the crops.

VERMICOMPOST

Vermicompost is the product of earthworm digestion and aerobic decomposition using the activities of micro- and macroorganisms at room temperature. Vermicomposting, or worm composting, produces a rich organic soil amendment containing a diversity of plant nutrients and beneficial microorganisms.

There are several benefits for vermicomposting but the two most popular are (1) diverting organic residuals from the landfill and reducing trash collection fees and (2) creating resources from waste materials.

Vermicomposting can be a fun activity for school children, and vermicompost can be utilized in gardens to promote plant growth. Vermicompost can be mixed with potting media at a rate of

10% by volume or else added directly into your soil; both options will provide plants with valuable organic matter, nutrients, and a diversity of beneficial microbes.

Earthworm biology

Typical earthworms that you find in your garden are not suitable for vermicomposting. These are soil-dwelling worms that do not process large amounts of food waste and don't reproduce well in confined spaces. Instead, worms commonly known as redworms or red wigglers are preferred because they reproduce rapidly, are communal and tend to remain on the surface while feeding.

There are several species of vermicomposting worms but the most common are Eisenia fetida and E. andrei. Red wigglers are hermaphrodites having both male and female reproductive parts; however, it still requires two worms to mate with each worm donating sperm to the other worm.

Under ideal conditions, a worm bin population can double about every 2 months (4-6 weeks from cocoon to emergence and 6-8 weeks from emergence to maturity). The "band" around a worm, known as the clitellum, indicates maturity and is reproductively active. Cocoons are about the size of a match stick head, turning pearly white to brown as they develop until one to several baby worms hatch.

Red wigglers require similar conditions as humans for growth – they prefer room temperature (55-85°F) and adequate moisture. The population of a worm bin is controlled through nutrient/food availability and space requirements.

Building a worm bin

There are a number of bins that can be used to raise earthworms, some of the more common are plastic bins of various sizes. Worm bins can be made of wood but cedar should never be used as it contains antimicrobial properties. Commercial bins can also be purchased online. Bins made from 1-2 inch thick Styrofoam have proven to be a suitable alternative to plastic bins with the added advantage of better insulation and can be acquired for free from fish/pet supply stores. Smaller bins are fitting for those just starting out but will restrict population growth while larger bins, usually 18 inches wide, 24 inches long and 18 inches deeps are typical for larger worm populations.

What is Vermicomposting?

Vermicomposting is the scientific method of making compost, by using earthworms. They are commonly found living in soil, feeding on biomass and excreting it in a digested form.

Vermiculture means "worm-farming". Earthworms feed on the organic waste materials and give out excreta in the form of "vermicasts" that are rich in nitrates and minerals such as phosphorus, magnesium, calcium and potassium. These are used as fertilizers and enhance soil quality.

Vermicomposting comprises two methods:

- **Bed Method:** This is an easy method in which beds of organic matter are prepared.
- **Pit Method:** In this method, the organic matter is collected in cemented pits. However, this method is not prominent as it involves problems of poor aeration and waterlogging.

Process of Vermicomposting

The entire process of vermicomposting is mentioned below:

Aim

To prepare vermicompost using earthworms and other biodegradable wastes.

Principle

This process is mainly required to add nutrients to the soil. Compost is a natural fertilizer that allows an easy flow of water to the growing plants. The earthworms are mainly used in this process as they eat the organic matter and produce castings through their digestive systems.

The nutrients profile of vermicomposts are:

- 1.6 per cent of Nitrogen.
- 0.7 per cent of Phosphorus.

- 0.8 per cent of Potassium.
- 0.5 per cent of Calcium.
- 0.2 per cent of Magnesium.
- 175 ppm of Iron.
- 96.5 ppm of Manganese.
- 24.5 ppm of Zinc.

Materials Required

- Water.
- Cow dung.
- Thatch Roof.
- Soil or Sand.
- Gunny bags.
- Earthworms.
- Weed biomass
- A large bin (plastic or cemented tank).
- Dry straw and leaves collected from paddy fields.
- Biodegradable wastes collected from fields and kitchen.

Procedure

1. To prepare compost, either a plastic or a concrete tank can be used. The size of the tank depends upon the availability of raw materials.
2. Collect the biomass and place it under the sun for about 8-12 days. Now chop it to the required size using the cutter.
3. Prepare a cow dung slurry and sprinkle it on the heap for quick decomposition.
4. Add a layer (2 – 3 inch) of soil or sand at the bottom of the tank.

5. Now prepare fine bedding by adding partially decomposed cow dung, dried leaves and other biodegradable wastes collected from fields and kitchen. Distribute them evenly on the sand layer.
6. Continue adding both the chopped bio-waste and partially decomposed cow dung layer-wise into the tank up to a depth of 0.5-1.0 ft.
7. After adding all the bio-wastes, release the earthworm species over the mixture and cover the compost mixture with dry straw or gunny bags.
8. Sprinkle water on a regular basis to maintain the moisture content of the compost.
9. Cover the tank with a thatch roof to prevent the entry of ants, lizards, mouse, snakes, etc. and protect the compost from rainwater and direct sunshine.
10. Have a frequent check to avoid the compost from overheating. Maintain proper moisture and temperature.

Result

After the 24th day, around 4000 to 5000 new worms are introduced and the entire raw material is turned into the vermicompost.

Advantages Of Vermicomposting

The major benefits of vermicomposting are:

1. Develops roots of the plants.
2. Improves the physical structure of the soil.
3. Vermicomposting increases the fertility and water-resistance of the soil.
4. Helps in germination, plant growth, and crop yield.
5. Nurtures soil with plant growth hormones such as auxins, gibberellic acid, etc.

Disadvantages of Vermicomposting

Following are the important disadvantages of vermicomposting:

1. It is a time-consuming process and takes as long as six months to convert the organic matter into usable forms.
2. It releases a very foul odour.
3. Vermicomposting is high maintenance. The feed has to be added periodically and care should be taken that the worms are not flooded with too much to eat.
4. The bin should not be too dry or too wet. The moisture levels need to be monitored periodically.
5. They nurture the growth of pests and pathogens such as fruit flies, centipede and flies.

Vermicomposting turns the kitchen waste and other green waste into dark, nutrient-rich soil. Due to the presence of microorganisms, it maintains healthy soil.

Vermicomposting is an eco-friendly process that recycles organic waste into compost and produces valuable nutrients.

MUSHROOM CULTIVATION

Mushrooms are the fruiting bodies of a fungus, just like apples are the fruiting bodies of an apple tree. A mushroom is a kind of fungus with the Latin name of Agaricus bisporus. Other cultivated mushrooms in the Netherlands are the oyster mushroom (Pleurotus ostreatus) and the shiitake (Japanese mushroom) (Lentinula edodes).

In the vegetable kingdom the mushroom is ranked with the heterotrophic organisms (lower plants). In contrast to the higher, green plants, these heterotrophs are not capable of photosynthesis. Fungi are the scavengers of nature. In mushroom cultivation too, waste products such as chicken manure, horse manure, straw, gypsum and waste water (from their own composting) are used to produce a high-quality substrate from which the mushrooms will grow. Ammonia is removed by means of an ammonia washer from the process air before it is returned to nature. Even the ammonia from the air is used as a source of nitrogen in composting. The fungus, also called mycelium, uses the compost as a source of energy for its combustion, in which energy is released that is used for growth.

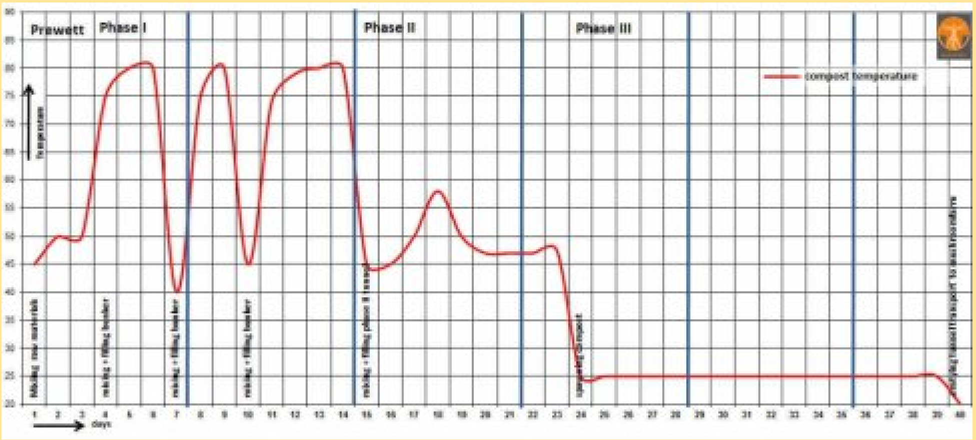
INTRODUCTION COMPOSTING AND CULTIVATION

Mushrooms grow on compost. The compost is produced at specialized companies. From the moment the raw materials are mixed, up to delivery of the compost to the mushroom farms. The process takes four to six weeks, depends depending on the raw materials and the system used at the Compost yard.

When the compost has been delivered at the mushroom farm, it still takes 16 to 20 days before a start can be made with mushroom harvesting. Harvesting takes place during two to three weeks. After this it is no longer cost-effective to harvest.

THE COMPOSTING DIAGRAM

In the diagram below you can read the various phases. All these phases take place at the composting company.



Phase I

Phase II

Phase III

PRODUCING FRESH COMPOST

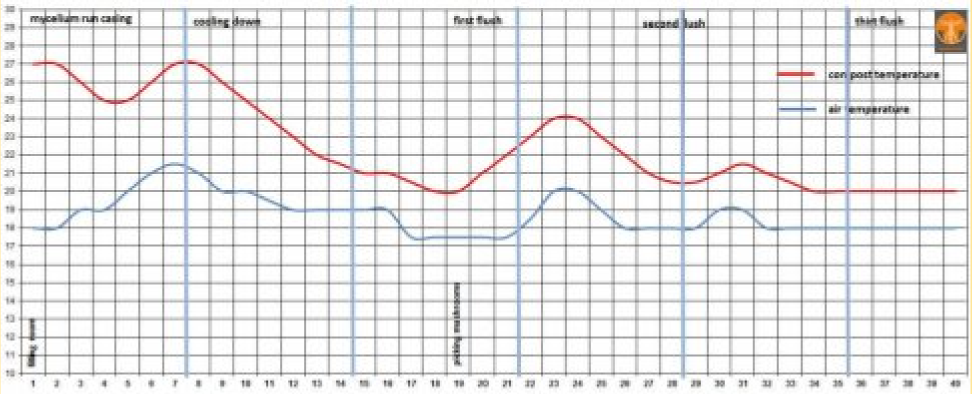
Depending on the raw materials this phase takes a minimum of 5 up to even 18 days. The most important objectives in this phase are:

- Mixing the straw or horse manure (this can replace the straw to a large extent) chicken manure, gypsum and water, so that the compost becomes homogeneous;
- Opening up the straw, so that the straw absorbs water and the mushroom fungus, the mycelium, can grow in the straw.

After this phase, the compost is called “phase I-compost”, “fresh compost”.

THE CULTIVATION DIAGRAM

In the diagram below you find the cultivation diagram at a mushroom farm.



ILLING THE ROOM

The phase-III-compost is transported to the farm. At the farm the cultivation room is filled with compost with a special filling machine. A cultivation room is a climate-controlled room with racks (Dutch shelf system).

During filling the compost is put in a layer of 20 cm with on top a layer of 5 cm of casing soil. This layer is pulled into the shelf system of the cultivation room. Casing soil consists of a peat mixture, mixed by a specialized company. At farms where they do phase III themselves, the compost remains in the room, but after 14-18 days, a layer of casing soil is put on the compost.

COOLING DOWN

When the mycelium has grown to the surface, the grower starts cooling down. Cooling down is an imitation of harvest conditions. Because of colder air and lower CO_2 the fluffy mycelium starts to contract. If the mycelium has contracted, 5-6 days after cooling down, it forms pins, which in the mushroom industry called pin or pinhead. These pins , (as big as pin-heads) are the mushroom primordia. This period is called pin formation. After this Relative Humidity (RH) in the room is slowly lowered, so that the pins start growing into mushrooms. From pin to harvestable mushroom takes 5 to 7 days. The period after growing out of the pins is sometimes called “phase IV”.

COOKOUT

At the end of the cultivation the cultivation room and the spent compost may be heated to 70º C. This should be done for a minimum of 8 hours, to kill all diseases and pests. Cookout is often omitted for economic reasons and is only done when diseases and pests are actually present. After harvesting and cookout the compost may be removed from the room and after cleaning the room a new cultivation cycle can be started.

Introduction to Mushrooms

Importance & History Importance:

• Mushrooms are being used as food since time immemorial. These have been considered as the delicacy. From the nutrition point of view mushrooms are placed between meat and vegetables.

• These are rich in protein, carbohydrate and vitamins. Mushrooms are low in caloric value and hence are recommended for heart and diabetic patients. They are rich in proteins as compared to cereals, fruits and vegetables. In addition to proteins (3.7 %), they also contain carbohydrate (2.4 %), fat (0.4%), minerals (0.6 %) and water (91%) on fresh weight basis. Mushrooms contain all the essential nine amino acids required for human growth. Mushrooms are excellent source of thiamine (vitamin-B1), riboflavin (B2), niacin, pantothenic acid, biotin, folic acid, vitamin C, D, A and K which are retained even after cooking. Since mushrooms possess low caloric value, high protein, high fibre content and high K: Na ratio, they are ideally suited for diabetic and hypertension patients. They are also reported to possess anticancer activities.

• India is primarily agriculture based country blessed with a varied agro-climate, abundance of agricultural waste and manpower, making it most suitable for cultivation of all types of temperate, subtropical and tropical mushrooms. It can profitably be started by landless farmers, unemployed youths and other entrepreneurs. It requires less land as compared to other agricultural crops and is basically an indoor activity. These are the ideal tools for recycling the agricultural wastes which otherwise may pose problem of disposal and atmospheric pollution.

• Therefore, mushroom cultivation is not only of economic importance but also has important role to play in integrated rural development programme by increasing income and self employment opportunities for village youths, woman folk and housewives to make them financially independent.

History

A.Button mushroom

• 1630: Cultivation of white button mushroom started first in France in the open on ridges made out of horse dung manure.

• 1707:Tournefort at Royal Academy of Science, France, mentioned about compost preparation and mushroom cultivation.

• 1731: French method of cultivation was introduced into England by Miller.

• 1779: Abercrombie described a method of composting stable horse manure in stacks.

• 1831: Callow grew mushroom in cropping houses warmed by fire heat and got fairly good yield (1.5 lbs/sq.ft)

• 1893:Costanitin pointed out that the incidence of diseases made constant changing of growing area necessary.

• 1902: Ferguson published details of spore germination and growing of mycelium.

• 1905: Duggar succeeded in making mycelium cultures from the tissue of mushroom caps.

• 1929: Lambert discovered that spawn could also be prepared from single spore cultures.

• 1937:Sinden found that about one third of monospore cultures of A.bisporushe prepared were incapable of producing fruit bodies.

• 1950:Sinden and Hauser introduced ―Short Method ‖ of composting.

• 1973: The first strain of A.bitorquis introduced commercially by a French firm Somycel as strain No. 2017 and later by Le Lion

B. Oyster mushroom

• 1917: Falck described the first successful cultivation of Pleurotusostreatus.

• 1951:Lowhag was the first to grow Pleurotus on sawdust mixtures.

• 1962: Bano and Srivastava reported mass production on straw-based substrates and their work paved the way for large scale commercial exploitation.

History of Mushroom Cultivation in India

Cultivation of edible mushrooms in India is of recent origin, though methods of cultivation for some were known for many years. The important historical developments in the cultivation of edible mushrooms are as below

• 1886: Some of specimens of mushrooms were grown by N.W. Newton and exhibited at the annual show of Agriculture, Horticulture Society of India.

• 1896-97:Dr. B.C. Roy of the Calcutta Medical College carried out chemical analysis of the local mushrooms prevalent in caves or mines.

• 1908: A thorough search of edible mushroom was initiated by Sir David Pain.

• 1921: Bose was successful in culturing two agarics on a sterilized dung medium, details of which were published in the Indian Science Congress held at Nagpur during 1926.

• 1939-45: Attempts on experimental cultivation of paddy straw mushroom (Volvariella) was first undertaken by the Department of Agriculture, Madras.

• 1941:Padwick reported successful cultivation of Agaricusbisporusfrom various countries but without much success in India.

- 1943: Thomas et al. gave the details of cultivation of paddy straw mushroom (V. diplasia) in Madras.
- 1947:Asthana reported better yields of paddy straw mushroom by adding red powdered dal to the beds. He suggested April-June as the most suitable period for cultivating this mushroom in central Provinces and also carried out the chemical analysis of this mushroom.
- 1961: A scheme entitled ―Development of mushroom cultivation in Himachal Pradesh‖ was started at Solan by the H.P. State Govt. in collaboration with I.C.A.R. This was the first serious attempt on cultivation of Agaricusbisporusin the country.
- 1962: Banoet al. obtained increased yield of Pleurotus on paddy straw.
- 1964: Cultivation of Agaricusbisporus on experimental basis was started by CSIR and State Govt. at Srinagar in J&K.
- 1965:Dr. E.F.K. Mantel, F.A.O., Mushroom Expert, guided and assisted Department of Agriculture for construction of modern spawn laboratory and a fully air conditioned mushroom house. Research on evaluation of different strains and use of various agricultural wastes, organic manures and fertilizers for preparing synthetic compost were undertaken. Dr. Mantel's consultancy concluded after a period of 7 years.
- 1974:Dr.W.A. Hayes, F.A.O., Mushroom Expert, guided further in improving the method of compost preparation, pasteurization and management of important parameters in the mushroom house. New compost formulations, casing materials and important parameters like nitrogen content in the compost, moisture in the casing mixture, air movements and maintenance of proper environmental factors were also standardized which raised the mushroom yields from 7 to 14 kg/m^2.
- 1977: A 1.27 crore, Mushroom Development Project was launched under U.N.D.P by the Department of Horticulture (H.P) wherein the services of Mr. James Tunney were made available. He got a bulk pasteurization chamber constructed and made available readymade compost and casing to the growers of H.P. The U.N.D.P. Project was concluded during 1982 and since then the Department of Horticulture (H.P) is running the project.
- 1982: The Indian Council of Agricultural Research (ICAR) sanctioned the creation of National Centre for Mushroom Research and Training (NCMRT) during VIth plan on October 23, 1982 with the objectives of conducting research on mushroom production,

preservation and www.AgriMoon.Com 6 MUSHROOM CULTURE utilization and to impart training to scientists, teachers, extension workers and interested growers.

• 1983: All India Coordinated Project on Mushroom (AICRPM) was initiated during VIth FiveYear Plan on 01.04.1983 with its headquarter at National Research Centre for Mushroom Presently known as Directorate of Mushrooms.

• Presently there are ten co-ordinating and one co-operating centres working under AICRPM located in 11 states. Of these,nine centres are based at State Agricultural Universities, while two at the ICAR institutes.

Classification of Mushrooms Classification of Mushrooms

• Mushroom is a fleshy fruiting body of some fungi arising from a group of mycelium buried in substratum.

Most of the mushrooms belong to the Sub- Division: Basidiomycotina and a few belong to Ascomycotina of Kingdom-Fungi.

• It is reported that there are about 50,000 known species of fungi and about 10,000 are considered as edible ones. Of which, about one hundred and eighty mushrooms can be tried for artificial cultivation and seventy are widely accepted as food. The cultivation techniques were perfected for about twenty mushrooms and about dozen of them have been recommended for commercial cultivation. However, only six mushrooms are widely preferred for large-scale cultivation.

They are :

1. Paddy straw mushroom - *Volvariella* spp.
2. Oyster mushroom - *Pleurotus* spp.
3. Button mushroom -*Agaricus* spp.
4. Milky mushroom - *Calocybe* spp.
5. Shiitake mushroom _ *Lentinulla* spp.
6. Jew’s ear mushroom - *Auricularia* sp.

Mushroom Poisoning and treatments

Eating poisonous mushrooms may cause different types of reactions which can broadly be classified as follows :

1. Gastric disorder: The poison causes serious gastric disturbance, it chiefly acts by exciting and then paralysing the central nervous system as by *Amanita muscaria* or poison containing

irritant which cause gastric enteritis by direct action on the mucous membrane of the digestive system.e.g Gyromi traesculenta.

2. Nervous disorder: It causes degeneration of cells , especially of the nervous system and grandular parenchymatous tissues like liver as in case of *Amanita phalloides.*

3. Muscular disorder: There may be exciting of the muscular system , especially the smooth muscular fibre as it is there in the uterus , vessels etc.

4. Haemolytic disorder: There can be destruction of blood or haemolysis as in case of Amanita rubescens.

Mulberry cultivation

Mulberry (Morus spp., Moraceae)

The important character of the members of the family Moraceae (especially Morus spp.) is the presence of idioblast, an enlarged epidermal cell in the leaf.

Ecological requirements

Climate

Mulberry can be grown upto 800 m MSL. For the optimum growth of mulberry and good sprouting of the buds, the mean atmospheric temperature should be in the range of 13oC to 37.7oC. The ideal temperature should be between 24 and 28oC with relative humidity of 65 to 80 percent and sun shine duration of 5 to 12 hours per day.

Mulberry can be grown in a rainfall range of 600mm to 2500mm. Under low rainfall conditions, the growth is limited and requires supplemental irrigation. On an average, 50mm once in 10 days is considered ideal for mulberry.

Soil

Slightly acidic soils (6.2 to 6.8 pH) free from injurious salts are ideal for good growth of mulberry plant. Saline and alkaline soils are not preferred.

Mulberry varieties

Irrigated : Kanva 2, MR 2, S 30, S 36, S 54, DD (Viswa), V1

Semi irrigated : Kanva 2, MR 2

Rainfed : S 13, S 34, RFS 135, RFS 175, S 1635

Propagation of mulberry

- Mulberry is mostly propagated through cuttings.
- Cuttings may be planted straight away in the main field itself or nursery may be raised and the sprouted and rooted saplings may be planted in the main field.
- The latter method is advisable because of its easy establishment in the main field.

Selection of planting material

- Generally, the mulberry plants are raised from semi-hardwood cuttings.
- Cuttings are selected from well established garden of 8-12 months old.
- Only full grown thick main stems, free from insect and disease damages having a diameter of 10-12mm are chosen for preparation of cuttings.
- The cuttings should be of 15-20 cm with 3-4 active buds and should have 45o slanting cut at the bottom end.
- Care should be taken to make a sharp clean cut at both the ends of cuttings without splitting the bark.
- Manually/power operated mulberry cutter (stem cutting machine) is available for quick cutting of propagation material.

Nursery

Nursery bed preparation

- Select 800 sq.m. area of red loamy soil near water source for raising saplings for planting one hectare of main field.
- Apply 1600 kg of Farm Yard Manure (FYM) @ 20 t/ha and mix well with the soil.
- Raise nursery beds of 4m x 1.5m size.
- The length may be of convenient size depending upon the slope, irrigation source, etc.

- Provide a drainage channel and avoid shady area.

Pre-treatment of cuttings

- Mix one kilogram of *Azospirillum* culture in 40 liters of water.
- Keep the bottom end of the cuttings for 30 minutes in it before planting. *Azospirillum* is applied for inducement of early rooting.

Nursery planting

- Apply VAM @ 100 g/m2 of nursery area.
- Irrigate the nursery bed. Plant the cuttings in the nursery at 15 cm x 7 cm spacing at an angle of 45o.
- Ensure exposure of one active bud in each cutting.

Nursery management

- Irrigate the nursery once in three days.
- Dust one kg of any one of the following chemicals around the nursery bed to avoid termite attack.

1. malathion 5 D
2. quinalphos 1.5 D

To avoid root rot and collar rot, drench the soil with carbendazim 50 WP (2 g/l) or apply *Trichoderma viride* 0.5 g/m2 using rose can.

- After weeding, apply 100 g of urea/m2 between 55 and 60 days after planting at the time of weeding.

Age of sapling

- The saplings are ready for transplanting in the main field after 90-120 days of planting.

Planting methods

Paired row system : Plant the cuttings/saplings at a spacing of 75 / 105 cm x 90 cm. Raise intercrops in the wider inter row space (amenable for mechanization also).

Planting method	Spacing (cm)	
	Irrigated	**Rainfed**
Ridges and furrows	60 x 60 / 90x90	90 x 90
Pit system	90 x 90	90 x 90

No. of cuttings / ha. - 27,780 (60 x 60 cm) ; 12,345 (90 x 90 cm)

Time of planting

- Plant during rainy season
- Avoid planting during winter and summer months

Planting of saplings

Plant the well rooted and sprouted saplings at a depth of 15-20 cm

- Earth up and level the area around the saplings
- Gap fill during monsoon months.

Nutrient management

a) Irrigated / semi irrigated (kg/ha)

	Row system			**Pit system**		
	N	**P**	**K**	**N**	**P**	**K**
Recommendation	300	120	120	280	120	120
Split doses						

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

- For V1, fertilizer schedule is 375 : 140 : 140 kg NPK/ha.
- Apply fertilizers as per soil recommendation wherever possible
- Apply the first dose of fertilizers three months after planting
- Follow subsequent fertilizer application after each leaf harvest and pruning
- Apply straight fertilizers to minimize the cost

b) Rainfed (Kg/ha)

	N	**P**	**K**
Recommendation	100	50	50
First dose	50	50	50
Second dose	50	-	-

- Apply the first and second doses coinciding with South West and North East monsoons respectively.

Bio-fertilizers

- Apply *Azospirillum* @ 20 kg/ha in five split doses. Apply phosphobacterium @ 10 kg/h in two equal splits.
- Mix the bio-fertilizers with 50 kg of FYM for uniform distribution
- Ensure irrigation after application
- Do not mix bio-fertilizers with inorganic fertilizers
- Growing and insitu incorporation of sunnhemp.

Micro nutrients

- Apply recommended major/secondary nutrients based on the deficiency symptoms.
- For micro nutrients according to the deficiency symptom expressed, apply micronutrients as foliar spary @ Zinc sulphate 5 g, Ferrous sulphate 10 g, Borax 2.5 g, Copper sulphate 2.5 g, Manganese 2.5 g or Sodium molybdate 100 mg/lit of water using high volume sprayer (spray fluid 500 lit/ha).
- Add wetting agent, Teepol @ 0.5 ml/lit. for better adherence on the foliage.

Methods of Irrigation

Ridges and furrows method

- Most efficient method of irrigation
- Comparatively requires less amount of water
- The furrows serve as drainage channels during heavy rainfall.

Flat bed method

- Rectangular beds and channels are formed
- Water run off is relatively low
- More land is wasted and requires more labour for field preparation.

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Mulberry varieties

V1 and S36 are the high yielding mulberry varieties highly suitable for silkworm rearing. These two varieties produce nutritive leaf, which is essential for good growth of silkworm larvae. The characteristics of these two mulberry varieties are as follows:

S-36

- The leaves are heart shaped, thick and light green with glowing nature.
- The leaves have high moisture and more nutrient content.
- About 15,000 to 18,000 Kg of mulberry leaf per year from one acre.

V-1

- This variety was released during 1997 and very popular in the field.
- The leaves are oval, broad in shape, thick, succulent and dark green
- About 20,000 to 24,000 Kg of mulberry leaf yield can be obtained in a year.

Plantation system

Paired row system of plantation with (90 + 150) cm x 60 cm spacing is advantageous over the existing system of plantation with 90 cm x 90cm or 60 cm x 60 cm spacing. The advantages of paired row plantation are

- Spacing between two paired rows facilitates the use of power tiller for intercultural operations and transportation of leaves. It also facilitates the use of drip irrigation system.
- Accommodates more number of plants /acre
- Easy and quick transportation of leaves, which reduces moisture loss.
- Saves labour up to 40% due to shoot harvesting.

Application of fertilizers and manure

- Apply FYM @ 20 MT / Ha/year in 2 equal split doses.
- Apply NPK @ 350:140:140 kg/ha/year for V1 and 300: 120: 120 Kg/Ha/year for S36 in 5 equal splits.

Irrigation

- Irrigate once in a week @ 80-120 mm.
- Wherever, there is water scarcity, the farmers can go for drip irrigation, so that 40 % of the irrigation water can be saved.

New method for raising mulberry in nursery

In sericulture, mulberry saplings are commercially produced from cuttings under raised or flat bed system.

The success of sprouting and vigour of the sapling are greatly influenced by competing weeds, soil moisture, and soil temperature. Since water and labour availability/expenditure on weeding are the hurdles nowadays, a new method of raising mulberry saplings using polythene sheets is developed to overcome these difficulties, which practically proved very effective for successful production of quality mulberry saplings for commercial purpose.

Method

After ploughing the land to 30 to 40 cm depth and application of 8 to 10 metric tonnes of farm yard manure, the land is to be levelled. Nursery beds are prepared with an irrigation channel three fourth common for both sides of beds.

Black polythene sheets cut to the size of 15 feet x 5 feet are to be placed on the bed and 6 to 8 months old disease-free mulberry cuttings (15 to 20 cm length with 3 buds) are to be inserted into the polythene-covered nursery bed soil at the spacing of 10 cm x 10 cm. Channel irrigation is to be done over the polythene itself once in a week or 10 days depending upon the soil texture of the area.

Benefits

1. By this method weeds can be totally arrested, as they do not get sunlight. Thus, no weeding is required throughout the nursery period (four months), which saves huge expenditure on manual weeding.
2. Since there are no weeds to compete with the growing mulberry saplings, they get the maximum soil nutrients, resulting in high vigour and growth, producing quality saplings. Unlike other methods, irrigation can be reduced to 50 per cent, as the polythene cover over the soil significantly reduces the soil temperature and prevents water evaporation, thus conserving soil moisture.
3. Income : By this method, about 2.30 to 2.40 lakhs saplings can be produced per acre in four months period with an increased average income of Rs. 50,000 over the other methods.

SERICULTURE

Rearing of Silkworm: In the beginning, the female silk moth lays hundreds of eggs. These eggs are stored over clean paper or a piece of cloth. These eggs are then sold to the silkworm farmers. The farmers then keep the eggs under the accurate temperature and humidity in a clean place. They are warmed to the most appropriate temperature to hatch eggs to produce larvae or caterpillars. This process is done when the mulberry trees have a fresh crop of leaves. The caterpillar eats these mulberry leaves day and night and it grows in size.

Bamboo trays are used to keep these caterpillars and some freshly chopped mulberry leaves are kept in the tray. After 30-40 days approximately the caterpillars stop eating the leaves and then moves inside the small chambers in the bamboo trays to spin cocoons. These are produced by the secretion of the liquid protein from their salivary glands. Small racks are given in the trays so that the cocoons get attached to those racks. Silk moths are developed inside the cocoons.

Processing Silk from Cocoons: These cocoons are used to obtain silk threads. When the cocoons are exposed to the sun or steam or boiled, the silk fib gets separated. This process of getting silk threads from the cocoons to use as a silk fabric is known as reeling of the silk. Reeling of the silk is carried out by special machines. These machines unwind the fibres of silk or threads from the cocoon. Silk fibres are then converted into silk threads to make different kinds of silk fabrics like silk sarees, etc. by the weavers.

Rearing Process of Silkworm step 1

Disinfection:

It is the most important operation that to be carried out prior to the commencement of rearing. Disinfection of everything including rearing places is carried out by physical, chemical or radiation methods.

(i) Physical methods

hese are cheap, convenient and easy to operate, e.g.

(a) Sunlight:

Drying of rearing appliances in sunlight can cause disinfection. However, sun drying cannot be carried out during winter and rainy seasons, and some appliances are likely to be damaged by exposure to sunlight,

(b) Steam:

Disinfection by steaming may be used for rearing room and some appliances (not made of bamboo or wood). However, initial cost for installing the steaming apparatus like boiler and pipeline is high.

(c) Hot air:

It is also a good sterilising method but cannot be used in routine sericulture because of its production cost.

(ii) Chemical method:

The most commonly used disinfection method in sericulture is chemical method. Chemicals generally used are non-toxic to man and animals, have broad spectrum activity, stable and readily mixable with water and fair in cost.

Most frequently used chemicals include chlorine as chloramine, iodine as iodophores, phenol as cresol and hexachlorophene, formaldehyde as formalin (2%), bleaching powder, etc. These are used as spray or fumigant. Precautions should be taken during and after the applications of such chemicals.

Rearing Process of Silkworm: Step 2.

Brushing:

Brushing is the separation of newly hatched larvae from their egg shells and transferring them to rearing trays from the egg cards. The newly hatched larvae are black, bristly and called ants.

Brushing is usually starts at 10 am when peak hatching occurs. Brushing can be done by various ways:

(a) Brushing from loose eggs:

Fine meshed net or thin muslin cloth can be placed over the newly hatched larvae. Then freshly chopped mulberry leaves are sprinkled over that net / cloth. The larvae start to crawl up through the holes onto the leaves. After sometimes, the larvae along with leaves are gently tapped on the rearing bed.

(b) Brushing from egg cards:

From egg cards, newly hatched larvae can be transferred by the following:

(i) Feather:

Here the egg card is held vertically above freshly prepared rearing bed and then by gentle strokes of a feather, the larvae are pulled out from the card on the rearing bed. However, this method is little bit crude and may cause some injury to the larvae.

(ii) Husk:

Here powdered husk is sprinkled over newly hatched larvae on the egg card. Then freshly cut mulberry leaves are sprinkled over the centre of husk. The larvae crawl up the husk to reach the leaves. After sometimes, the larvae are brushed from husk by means of a feather on the rearing bed.

However, in all cases of brushing, care should be taken not to touch the newly hatched larvae with hands.

Rearing Process of Silkworm: Step 3.

Feeding the Larvae:

Both the quality and size of the cocoons depend mainly on the quality of mulberry leaves fed by larvae during rearing. After a little practice, the amount of leaves that to be given per feeding to fulfill the appetite of the worms, is adjusted. The amount of food given also d epends on races and voltinism of the moths.

However, maximum amount should be given during the active feeding stage of instar and no food should be given during moulting. In Indian sericulture, nowadays four feedings per day is allowed. In case of shoot and floor rearings, three feedings per day are sufficient.

In all larvae, several feeding stages can be noticed during their development, viz., active feeding stage when larvae feed maximum during the instar, sparsely feeding stage when they eat less, usually at premoulting stage when larvae empty their gut; non-feeding stage when the larvae do not take any food usually during moulting.

Of the total ingestion during entire larval development, nearly 85% of food is taken during IVth and Vth instar stages. Leaf requirement during different instar stages are given

Table 3.2 : Leaf requirement (in kg) for 50 DFLs or 2000 eggs of different races of larvae

Larval instar	Uni-/bi-voltine race	Multivoltine race
1st Instar	1-2	1-2
2nd Instar	5-6	2-3
3rd Instar	20-55	15-20
4th Instar	80-90	35-50
5th Instar	450-475	300-325

During feeding, generally a gap of 2 hours is given before and after each moulting. Young

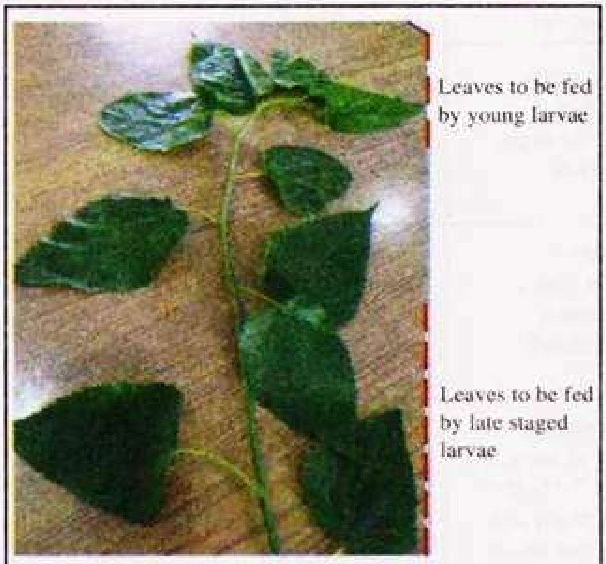

Fig. 3.44. Mulberry leaves for warm-feed

worms are always fed with tender leaves while late stages are given mature mulberry leaves. To enable the larvae to feed easily, young worms have to be given chopped leaves but for mature worms, full leaves or young branches or shoots may be given.

Rearing Process of Silkworm: Step 4.

Spacing:

The silkworms grow very rapidly from age to age and increase many times their weight and size from the previous instar. The total increase in weight from hatching to the end of Vth instar is about 7,000 to 10,000 times.

Crowded situation in rearing trays results in increased humidity, heat, fermentation of litter, all of which will in turn cause under development of larvae, wastage of feeding leaf and unhygienic condition. To provide more and adequate space for the growing worm, the rearing space has to be extended at each stage and this is called spacing.

Spacing is usually done along with bed cleaning and is given once a day. The number of trays and space required for each instar are given below

Table 3.3 : Number of trays and area of space required by different instars of silkworm during rearing

	No. of trays required for 100 DFLs (diameter of tray 3.5')		Space required (sq. ft) (Bi/multivoltine)	
Stage of silkworm	Beginning	End of stage	Beginning	End of stage
1st instar	2	2	4	15
2nd instar	2	5-6	15	45
3rd instar	5-6	10-12	46	90
4th instar	10-12	20	91	180
5th instar	20	40	181	360

Rearing Process of Silkworm: Step 5.

Bed Cleaning:

The rearing tray of silkworms accumulates some unconsumed leaves after each feeding, exuviae after moulting, excreta, dead or diseased larvae, etc. All these if not cleaned, combine to form a thick and damp litter which promotes the growth of different micro-organisms, generation of heat and injurious gases and depletion of oxygen.

Hence, it is very necessary to remove the litter periodically and the process of its removal is called bed cleaning.

Bed cleaning can be done by using paddy husk, straw and bed cleaning net (Fig. 3.10a). During 1st instar, bed cleaning should be done once during per moulting, during 2nd instar twice, once after moult and before next moult.

During 3rd instar thrice, i.e. after moult, before next moult and once in the middle. During 4th and 5th instars once in a day in case of shelf rearing. However, in case of floor or shoot rearing, bed cleaning should be done once in each instar.

Fig. 3.10(a). Bed cleaning by net

Rearing Process of Silkworm: Step 6.

Caring during Moulting:

In commercial races of silkworm, moulting occurs four times, lasting for 15-30 hours. During this time, the worm does not take any food, wriggles out of the old skin and comes out with a new, soft skin.

Care taken during moulting includes stopping and resuming feeding at appropriate time to ensure uniform growth, keeping the bed dry and disinfected either by dusitng Resham Keed Oushad (RKO), formulated by CSR and TI, Mysore or by spraying Labex, formulated by Berhampur.

Besides disinfecting action, RKO can reduce grasserie in different seasons and can increase growth rate of larvae leading to improved cocoon quality. Labex has anti muscardine effect and can inhibit early moulters from resuming feeding leading to uniform growth.

Rearing Process of Silkworm: Step 7

Mounting:

Mounting is the process of transferring the ripe worms to the mountages. On the mountage, the ripe worms exude silk, spin the cocoon around itself and transformed into the pupa inside it. The pupa after metamorphosing into adult moth comes out by piercing open the cocoon.

The aim of sericulture is to rear the silkworm providing them optimum conditions and mountages so that they can spin good cocoon with high and best silk content.

Mounting is done by following methods:

(i) Hand picking:

Ripe worms are collected in a tray one by one by hand and then transferred to the mountages. Though some worms may be injured while picking and handling, but by this method, only ripe worms can be picked and distributed more uniformly in the mountages

Fig. 3.10(b). Mounting of ripe worm on Chandrika by hand-picking

(ii) Simultaneous mounting:

In this method, a number of mature larvae is collected simultaneously and transferred to the mountage. Here, mature, immature and over-mature worms are mounted together; hence, cocoon formed by them may not be uniform.

(iii) Net method:

In the rearing tray, when worms are ripen, straw rope nets / rush nets or cleaning nets are spread over the rearing beds and left for some time. Ripe worms crawl alone on the nets while unripe worms continue feeding. The nets with ripe worms are then shaken on the mountages to transfer them without touching by hand.

(iv) Branch method:

Here small branches of mulberry are spread over the rearing bed. Ripe worms craw ling over them are then shaken off on the mountages. Besides branch, dried weeds (Russia) or cut straw (Japan) can also be used for transferring the ripe worms to mountages.

Number of ripe worms per mountage is very important. In general, one ripe worm requires an area that is the square of its body length for spinning its cocoon.

Too wide spacing may cause wastage of silk for spinning the preliminary web. Again, too close spacing may result in formation of double cocoon (which are not reelable), staining of cocoons with excreta of the worms and also formation of damp cocoons. The optimum density for Chandrika is 50 worms per 0.1 m^2.

Precautions to be taken during mounting:

(i) Only ripe worms should be mounted. Unripe worms spoil other cocoons with their excreta while overripe worms hastily spin cocoons which are malformed, flattened, sticky and inferior.

(ii) An optimum temperature (24°C) should be maintained in spinning place. Too low temperature causes delayed formation of cocoons, and affects colour, lustre and texture of the silk. Too high temperature results in the formation of deformed cocoons with thick filament.

(iii) The ideal humidity for spinning is 60-70%. Ventilation is needed to dry the wet silk into firm cocoon and to evaporate the water or excreta released by the worms during spinning.

(iv) The mountages should be disinfected before and after use.

The spinning worms should not be disturbed which otherwise would result suspension of spinning and breaking of thread.

Common weeds of mulberry

Mulberry (*Morus* spp), the traditional feed for the silk worm, has been selected and improved for leaf yield and quality in many environments and is spread throughout the world. Mulberry leaves are highly palatable and digestible (70-90 %) to herbivorous animals and can also be fed to monogastrics. Protein content in the leaves and young stems, with a good essential amino acid profile, varies from 15 to 28 % depending on the variety. Mineral content is high and no anti-nutritional factors or toxic compounds have been identified. The establishment of this perennial forage is through stakes or seed, and it is harvested by leaf picking or cutting whole branches or stems. Yields depend on variety, location (monthly temperature, solar radiation and rainfall), plant density, fertilizer application and harvesting technique, but in terms of digestible nutrients, mulberry produces more than most traditional forages. The leaves can be used as supplements replacing concentrates for dairy cattle, as the main feed for goats, sheep and rabbits, and as in ingredient in monogastric diets.

Mulberry weed (Fatoua villosa) gives growers and Extension Agents a lot of problems. Also called crabweed or hairy crabweed, it invades landscapes, field nurseries, and containerized ornamentals. In addition to Georgia, it has been reported in Arkansas, and all states East of the Mississippi from Florida to Indiana. Mulberry weed is a herbaceous annual, with a taproot. Leaves are alternate and serrated along the margins. Purplish green flowers are without petals, and are produced in 1 inch clusters (cymes) in leaf axils. The plant grows to 3 or 4 feet tall. Don't let weeds go to flower. If you see flowers, seeds are on the way, and they only led to more plants. ~ Keep vegetation mowed around production areas as far back as possible. ~ If you see any plants growing, eliminate them as soon as possible ~ Rotate pre-emergence herbicides so the plants are exposed to different herbicide chemistry. In other words, don't use Surflan followed by Factor. Both have the same mode of action. Instead, rotate to something like Gallery. For excellent weed control, try tank mixing Gallery with products like Surflan. It provides an excellent spectrum of weed control.

Propagation of mulberry.

Today mulberry is cultivated in about 2.90 lakh hectares in India and the stress is upon productivity. Earlier the mulberry production per hectare was around an average of 12,000 to 15,000 kgs of leaf under irrigated conditions. Presently the average production has been tremendously increased due to the adoption of new technology like proper maintenance of mulberry garden and planting high yielding varieties while the average mulberry production per hectare has enhanced from 25,000 kg to 35,000 kgs.

Propagation of Mulberry:

Mulberry can be propagated in two ways.

i. Sexual,

ii. ii. Asexual

i. Sexual Propagation:

In mulberry the sexual propagation is through seedlings, particularly the seed propagation carries a varied population, this to utilize in selection and hybridization. For seed germination certain prerequisites are needed to be fulfilled such as selection of quality seed, preparation of land, and the seed should be selected such that can definitely germinate. This is possible only when the seed is subjected to suitable environmental conditions, embryo of seed is alive, and healthy, in internal conditions of seed are favourable for germination.

The fresh seeds will have greater germination rate than the stored once. Seeds must be washed with fresh water until the flesh of fruit is withdrawn and dried well, however minimum moisture percentage should be maintained, i.e. at least 6 %. Sowing of seeds may be by way of broadcasting or sowing in lines.

ii. Asexual Propagation:

In asexual type of propagation vegetative plant parts are used. In mulberry the propagation is mainly of three types.

1.Propagation by Cutting.

2.Propagation by Grafting.

3.Propagation by Budding.

In case of mulberry, mostly through "Cuttings" only the propagation is practiced. By asexual method of propagation the inherited characteristics of parent stock can be retained. The desired characteristics can be carried to next generation. The asexual propagation in mulberry is carried out by grafting, cutting, layering.

ESTABLISHMENT AND MANAGEMENT OF MULBERRY GARDEN

Land preparation: Soil, leveling and ploughing

Soils with good water retention capacity with high amount of clay and organic matter are ideal for rice cultivation.

- Clay or clay loams are most suited for rice cultivation.
- Such soils are capable of holding water for long and sustain crop.
- Rice being a semi-aquatic crop, grows best under submerge conditions.
- Rice is cultivated in almost all types of soils with varying productivity.
- The major soil groups where rice is grown are riverine alluvium, red-yellow, red loamy, hill and sub-montane, Terai, laterite, costal alluvium, red sandy, mixed red, black, medium and shallow black soils.
- It grows well in soils having a pH range between 5.5 and 6.5.

Special technologies for problem soils: For fluffy paddy soils: compact the soil by passing 400kg stone roller or oil-drum with stones inside, eight times at proper moisture level (moisture level at friable condition of soil which is approximately 13 to18%) once in three years to prevent the sinking of draught animals and workers during puddling.

- **For sodic soils:** For sodic soils with pH values of more than 8.5, plough at optimum moisture regime, apply 50% of total gypsum requirement uniformly, impound water, provide drainage for leaching out soluble salts and apply green leaf manure at 5 t/ha, 10 to 15 days before transplanting. Mix 37.5kg of Zinc sulphate per ha with sand to make a total quantity of 75kg and spread the mixture uniformly on the leveled field. Do not incorporate the mixture in the soil. Rice under sodic soil responds well to these practices.
- **For saline soils:** For saline soils with EC values of more than 4 dS/m, provide lateraland main drainage channels (60cm deep and 45cm wide), apply green leaf manure at 5 t/ha at 10 to 15 days before transplanting and 25% extra dose of nitrogen in addition to recommended P and K and ZnSo4 at 37.5 kg/ha at planting
- **For acid soils:** For acid soils apply lime based on the soil analysis for obtaining normal rice yields. Lime is applied @ 2.5t/ha before last ploughing. Apply lime at this rate to each crop upto the 5th crop.

Ploughing Primary tillage Ploughing is the primary tillage operations, which is performed to cut, break and invert the soil partially or completely suitable for sowing seeds.

Special technologies for problem soils

- To obtain a deep seed bed of good texture.
- To increase the water holding capacity of the soil.
- To improve soil aeration. • To destroy weeds, insects and pests.
- To add fertility to the soil by covering vegetation

Secondary tillage Harrowing Harrowing is a secondary tillage operation which is done to a shallow depth for smoothening and pulverizing the soil as well as to cut the weeds and to mix the materials with the soil.

Purpose of harrowing

- To pulverize the soil of the seedbeds in the field.
- To destroy grasses and seeds in the field.
- To cut crop residues and mix them with top soil of the field.

To break the big clods and to make the field surface uniform and levelled.

- Harrowing is carried out when the moisture content of the clods are reduced.

Puddling

Puddling is churning the soil with water. It is done in paddy fields with standing water of 5-10 cm depth after initial ploughing with country plough. It breaks up the clods and churns the soil.

Purpose of puddling

- To reduce leaching of water or decrease percolation of water,
- To kill the weeds by decomposition.
- To facilitate transplantation of paddy seedlings by making the soil softer.
- To decrease water and nutrient losses by reduced hydraulic conductivity.

Levelling Land levelling is expected to bring permanent improvement in the value of land. Levelling work is carried out to modify the existing contours of land for efficient agricultural production system

Purpose of Levelling

- Efficient application of irrigation water and increased conservation of rain water.
- Improve surface drainage and minimize soil erosion
- Provision of an adequate field size and even topography for efficient mechanisation.
- Perfect land leveling for efficient weed and water management.
- Improves better crop stands and crop establishment

Plantation methods: Row and pit systems

Pit System

This system is followed for rain-fed crops and adopts a wider spacing. instead of ploughing the entire field, pits of standard size (40×40×40 cm) are dug with an inter-plant and inter-row distances of 90×90 cm for a bush type of cultivation, 180×90 cm for high bush cultivation and 270× 270 cm for a tree-type plantation. Equal quantities of organic manure, red soil and sand are placed in each pit after mixing and a cutting or a sapling is planted. Initially it is watered daily until rooting takes place. if tree type plants are to be grown on hedges, roadside, etc., the pits are of a larger size (45×45×45 cm).

Row System

This system is followed for irritation mulberry crops throughout South India. The land is prepared by ploughing ridges and furrows. The distance between the ridges is generally 45-60 cm. A rope with knots at equal distances of about 45-60 cm is tied from one end of a ridge to the opposite end, and two cutting are planted at the point indicated by the knot on either side of the ridge. Thus, the inter-plant distance between the rows and plants within the row is about 45-60 cm . Irrigation water flows through the furrows between the rows and generally the crop is grown as bush mulberry and is harvested by bottom pruning.

Present status of Sericulture

Sericulture at present is carried on in many parts of the world. India stands fifth in the production of silk. Theother major silk producing countries in order of production are Japan, China, South Korea, U.S.S.R., Brazil, Bulgaria and Italy. India accounts for little over 5% of the total global output of mulberry raw Silk and 10% of the tasar. However, it is only next to China in production of tasar Silk. Munga is specially an Indian variety. Probably India is the only country which produces all the four types of Silk viz., Mulberry, Tasar, Eri and Munga. Inspite of the challenge posed by the artificial Silk, the production of natural Silk has increased to about 40% in last 15 years and the global output of 1974 was 45 thousand tonnes. In India the major silk producing states are Mysore, West Bengal, Jammu and Kashmir, Assam, Bihar, Orissa, Madhya Pradesh, U.P., Andhra Pradesh, Tamil Nadu, Punjab, Manipur, Tripura and Maharashtra. The total annual production of raw silk in India is about 31 lakhs kg. out of which mulberry alone accounts the highest i.e., 25 lakhs kg. and non-mulberry is around 6 lakhs kg. The total output of Silk waste in India is about 12.5 lakhs kg. annually, out of which mulberry shares about 10 lakhs kg. and the rest is shared by non-mulberry Silk. The value of Silk- product in India is about Rs. 80 crores per annum. Export of Silk brings about Rs. 15 crores in foreign exchange. Mysore state has the distinction of producing alone about 76% of total production of raw silk in this country. In Mysore, W.B., J. and K,, T.N., Punjab and H.P. silk produced is mainly of mulberry type, whereas in the states of Assam, Bihar, Manipur, M.P., Orissa, silk produced is mainly of non-mulberry type. Bihar has the oldest set up of this industry and produces all the varieties except the munga. Bihar has also the privilege of producing tasar in largest quantity. The tasar production in the State is mainly based in SanthalPargana, Chotanagpur and Chaibasa districts. Altogether 16 tasar seed supply stations are functioning in Chotanagpur. The Eri Silk is mainly limited in the state at Gangetic plains. Ranchi, Patna, Bhagalpur, Monghyr, Muzaffarpur and Saran districts has Eri Seed Supply Station one each. 48 demonstration centres for spinning of Eri Silk have been established in the state. Mulberry Silk is restricted to Pumea district along the border of West Bengal. The total production of Silk is of the value of about 3—5 crores in Bihar. In Bihar alone about 1.25 lakh persons are engaged in different aspects of this industry. Rearing of silkworms on large scale is carried on in villages and remote forests by villagers and tribals. They are assisted by State Government and Central Government agencies. In each Silk producing state there is a special unit under State Government to look after this industry. Assistance in the form of money, seeds, technical know-how, insecticides etc. are provided to the rearers. This unit is also responsible for maintaining a liasion between rearers, weavers and cloth manufacturing industries.