Water Management Technologies for Sustainable Agriculture

Farmer's Participatory Action Research Programme

Water Technology Centre
Indian Agricultural Research Institute
New Delhi-110012

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Ministry of Water Resources

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Foreword

India occupies just 2.3% of the world's land area with only 4.6 % of the world's fresh water resources to feed 17% of the world's human population and 11% of its bovine population. As per the estimates of the Central Water Commission, India has 1,132 billion cubic metres of utilizable water, of which 690 billion cubic metres constitute the surface water and 432 billion cubic metres the groundwater. It receives about 400 Mha m of annual precipitation which is augmented by 20 Mha m contributed by rivers flowing in from neighboring countries. Water is a critical input for all production systems, whether based on crops or livestock. Ground water in different parts of the country has been over exploited resulting in several problems such as salinity and alkalinity of the soil and sharp decline in ground water table. The availability of water for agricultural sector is bound to decrease in future owing to fierce competition from industrial and power sectors and domestic users in urban areas.

Injudicious management of the country's water resources has drastically reduced the availability of water resources in India during the last 50 years. The decreasing per capita availability of water is posing a challenge for agricultural scientists to sustain and enhance agricultural productivity to meet the requirements of ever increasing human and livestock populations. To ensure sufficient availability of food, fodder, fibre and fuel for the present generation without leaving any stress on future generations, water use efficiency in agricultural production has to be improved. Adoption of improved water management technologies evolved by the agricultural research system on a large scale by the farmers will contribute significantly to the enhancement of agricultural productivity per unit volume of water. With this objective, the Ministry of Water Resources, Government of India had initiated the Farmers' Participatory Action Research Programme (FPARP) during the XI Five Year Plan which has been extended to the XII Five Year Plan. Under this programme, different water management technologies have been effectively demonstrated in farmers' fields by different research organizations across the country.

The Water Technology Centre of IARI, New Delhi has made tremendous contribution towards the promotion and transfer of water management technologies under phases I and II of the FPARP to benefit the farmers. This extension bulletin has been brought out by the scientists associated with the programme. I appreciate the efforts of these scientists in bringing into focus the different water management technologies available and congratulate them for bringing out this publication which will be of great use in capacity building of the farmers, extension workers and policy planners.

December 1, 2012 — **(H.S. Gupta)**
New Delhi — Director, IARI

Preface

Generally, the farmers' fields are poorly levelled, which leads to poor irrigation water distribution efficiency and about 20-25% of irrigation water is lost during its application. With intensive cropping system, organic carbon content of the soil is rapidly decreasing resulting in overall deterioration of physical, chemical and biological properties of soil. Almost all the cereal and vegetable crops have been conventionally planted by farmers in narrow spaced rows on flat surfaces or broadcast and irrigated by flood irrigation within check basins and border strips. Such flood irrigation results in low water use efficiency and depletion of soil nutrients. Traditional paddy cultivation of keeping the crop flooded with water for major crop period leads to low crop productivity /unit of irrigation water. Deep standing water in paddy field does not allow access of oxygen to roots, and more over results in increased methane release, a green house gas responsible for global warming. Generally under surface irrigation methods, only less than one half of the water released is utilized by the plant. A good part of the applied water is lost in conveyance, application, runoff and evaporation. Accordingly, the efficiency of surface irrigation methods is low.

It has been estimated that 80% of available water in India is being used for irrigation purposes. However the efficiency of water utilization at farmers' fields has been very low because of heavy water loses during conveyance and application at the field level. As a result of such poor water use efficiency in agriculture and ever increasing human and livestock population, the per capita availability of water has continuously been decreasing. The per capita availabity of surface water which used to be 2309 cubic meter in 1991 has decreased to 1902 cubic meter in 2011 and as per an estimate it will further decrease to 1401 cubic meter by 2025, putting at risk 30 % of our crop production. The decreasing per capita availability of water is posing a challenge for agricultural scientists to sustain and enhance the agricultural productivity.

Agriculture Research System has evolved a number of improved water management technologies for enhancing the agricultural productivity per unit volume of water. However, in spite of best efforts of state development departments and other extension agencies including NGOs, these technologies have not reached to a large number of farmers. It was with this objective of transferring these water management technologies to the farmers that the Farmers Participatory Action Research Programme was initiated during XI five-year plan by Ministry of Water Resources (MoWR). The programme was taken up throughout the country with the help of Agricultural Universities/ICAR Institutes etc. in form of five thousand hectare demonstrations of improved water management technologies on farmers' fields.

Under this programmes, Water Technology Centre, IARI New Delhi has successfully demonstrated five water management technologies to the farmers of three different operational areas i.e. Alwar district of Rajasthan, Jhajjar district of Haryana and Bulandshahar district of Uttar Pradesh. Based on their experiences with the farmers, the Scientists associated with the programme realized that detailed information on all these technologies is not available either with the development departments or with extension agenencies. To fulfil this gap the present extension brochure containing details of five water management technologies has been brought out. The brochure will be of great use in capacity building of the farmers, extension workers and planners for improving water use efficiency at field level.

Authors

Introduction and Objectives

Water is a critical input for all forms of life and production systems be it hydropower, industry or agricultural including crops, forestry, livestock, fisheries and poultry. Having limited resources for fresh water, it has to be managed judiciously with improved use efficiency so that it can be maintained to meet the need of mankind in times to come along with preservation of hydrological and biological functions of the eco system.

As per the Central Water Commission estimates, India is having 1132 billion cubic meter utilizable water resources of which 690 billion cubic meter is from surface water and 432 billion cubic metre from groundwater. It has been estimated that 80% of available water in India is being used for irrigation purposes. However, the efficiency of water utilization at farmers' fields has been very low because of heavy water loses during conveyance and application at the field level. As a result of such poor water use efficiency in agriculture and ever increasing human and livestock population, the per capita availability of water has continuously been decreasing. The per capita availability of surface water which used to be 2309 cubic meter in 1991 has decreased to 1902 cubic meter in 2011 and as per an estimate it will further decrease to 1401 cubic meter by 2025, putting at risk 30% of our crop production.

The decreasing per capita availability of water is posing a challenge for agricultural scientists to sustain and enhance the agricultural productivity. Agriculture Research System has evolved a number of improved water management technologies for enhancing the agricultural productivity per unit volume of water. However, in spite of best efforts of state development departments and other extension agencies including NGOs, these technologies have not reached to a large number of farmers. The agricultural productivity per unit volume of water can be improved only by transfer of the evolved water management technologies to the farmers' fields on a large scale. It was with this objective that the Farmers Participatory Action Research Programme was initiated during XI five-year plan by Ministry of Water Resources (MOWR) and the same has been extended during XII five-year plan. Under this programme different water management technologies have been demonstrated on farmer's field by different research organizations in different parts of the country.

Water Technology Centre at IARI New Delhi has successfully demonstrated following five water management technologies to the farmers in three different operational areas i.e. Alwar district of Rajasthan, Jhajjar district of Haryana and Bulandshahar district of Utter Pradesh.

- Laser Levelling for efficient irrigation.
- Enhancing water holding capacity and organic carbon content of soil through biogas slurry.
- Raised Bed Technology to achieve higher yield with less water.
- System of Rice Intensification (SRI) for paddy cultivation.
- Micro Irrigation

Therefore for promotion and transfer of all these technologies to a large number of farmers, detailed information on these five water management technologies is being included in this extension brochure for use of farmers, extension workers, NGOs and policy planners.

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CHAPTER 1

Laser Levelling for Efficient Irrigation

Generally, the farmers' fields are poorly levelled, creating localized water logged conditions in lower portion of the field and poor moisture in elevated portion of the field leading to uneven germination and poor crop stand. The total depth of water applied per irrigation is greatly influenced by the quality of land levelling. One of the hindrances in sustainable and remunerative crop production is undulating surface of the agricultural fields which cause limitations in many cultural practices. Such undulation and unevenness of the soil surface affect adversely crop germination, stand and yield mainly due to non-uniform moisture and nutrient distribution pattern. Unevenness leads to poor irrigation water distribution efficiency and about 20-25% amount of irrigation water is lost during its application due to poor farm designing and unevenness of the fields. The farmers adopt strip irrigation practice with field bunds leading to waste of fertile land in making bunds and borders. The excess moisture availability in low lying areas delays tillage and other soil manipulation operations. Fields that are not well levelled have uneven crop stands, increased weed burdens and uneven maturing of crops. All these factors tend to contribute to reduced yield and grain quality which reduce the income of the farmers.

1.1 Traditional methods of land levelling

Farmers traditionally have been practicing land levelling in their fields using animal drawn patta or wooden planket or tractor driven ordinary levellers consisting of a blade and a small bucket for shifting the soil from higher spot to the low laying parts (Fig. 1.1). The traditional method of land levelling

Fig. 1.1: Levelling by using conventional methods

includes surveying of the field, staking and designing the field, calculation of cuts and fills and then using a scraper and land planer to even the land. Despite all these labour-intensive efforts desired accuracy is not achieved. These levelling practices are crude and do not achieve a high level of smoothness of land surface. These methods of land levelling are also not designed to match the stream size, soil type, field size and slope and moreover they are tedious, time consuming, uneconomical and inaccurate.

1.2 Precision land levelling

It is important to achieve precision land levelling for efficient and judicious use of irrigation water in almost all the cereal and vegetable crops wherever surface irrigation techniques are used. Even for harnessing the effect of recommended cultural practices for crop cultivation and soil health improvement, land levelling is must. Thus, land levelling using modern technologies like Laser leveller aims at enhancing water-use efficiency, improving crop establishment, saving water, time and energy (electricity or diesel) and finally improve crop productivity and production. The importance of land levelling is catching on and farmers in many parts of the country now realize advantages of this technology and, therefore, pay serious attention in levelling their fields properly. This technology offers a great potential and with appropriate training can also provide useful employment to the farm youth through custom hiring.

The advanced method to level or grade the field is to use laser-controlled levelling equipment which provides a very accurate, smooth and graded field. This allows for ideal control of water distribution with negligible water losses. The precisely levelled surface leads to uniform soil moisture distribution and results in good germination, increased input use efficiency and crop yields. Precision land levelling helps in controlling the emergence of salt affected patches, increase in cropping intensity and crop productivity, increase in cultivable land area up to 3-5 %,improves crop establishment, reduces weed intensity and results in saving of irrigation water (Fig. 1.2). Laser levelling is the process of smoothening the land surface ±2 cm from its average elevation using laser equipped drag buckets to achieve


Fig. 1.2: Laser levelled field

precision in land levelling .Precision land levelling involves altering the fields in such a way as to create a constant slope of 0 to 0.2%. This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning system(GPS) and /or laser–guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level.

1.3 Considerations in laser levelling

There are certain prerequisites for land levelling to achieve high precision with less cost. The following should be considered for precise land levelling.

1.3.1 Field slope: Aslope of 0 to 0.2% is good for optimum water flow. The field should have a drain around it to facilitate water management, and small canals (e.g.,10-15 cm deep)from the middle of the field to the drainage points.

1.3.2 Infiltration: It is important to be aware of the physical properties such as infiltration rates of the sub –soil. In areas where a large amount of soil is moved and hard pans are removed, excessively high infiltration rate may lead to increased rates of nutrient and chemical leaching. Infiltration rate should at least match that of the surface soil.

1.3.3 Cost of levelling: The initial cost of land levelling using tractors and scarpers is high. The cost varies according to the topography, the shape of the field and the equipment used. By and large, the cost of land levelling with laser guided bucket on custom hiring comes up to INR 1500-2000 per ha in gently sloping fields. The cost of the levelling operation is two to three times that of a standard tillage operation.

1.4 Components of Laser Land Levelling System

The laser levelling involves the use of laser transmitter, that emits a rapidly rotating beam parallel to the required field plane, which is picked up by a sensor (receiving unit) fitted to a tractor towards the scraper unit. The signal received is converted into cut and fill level adjustment and the corresponding changes in the scraper level are carried out automatically by a hydraulic control system. The scraper guidance is fully automatic; the elements of operator errors are removed allowing consistently accurate land levelling.

A laser controlled land levelling system consists of following five major components viz.

1.4.1 Drag Bucket: The drag bucket can be either 3–point linkage mounted on or pulled by the tractor. Pull type system is preferred as it is easier to connect the tractor's hydraulic system to an external hydraulic ram than connectting to the internal control system used by the 3-point–linkage system. Bucket dimensions and capacity will vary according to the available power source and field conditions. A 60 H.P. tractor can pull a 2m wide × 1m deep bucket in most soil types. The design specifications for the bucket should match the available power from the tractor (Fig. 1.3).

Fig. 1.3: Drag bucket

1.4.2 Laser Transmitter: The laser transmitter mounts on a tripod, which allows the laser beam to sweep above the field (Fig.1.4). Several tractors with laser unit and drag bucket can work from one transmitter with guidance from laser receiver.

Fig. 1.4: Laser transmitter

1.4.3 Laser Receiver: The laser receiver is a multi directional receiver that detects the position of the laser reference plane and transmits this signal to the control box (Fig.1.5). The receiver mounts on a manual or electric mast attached to the drag bucket. It is mounted on the scraper. A set of controls allow the laser receiver to control the height of the bucket on the scraper. The operator can adjust the settings on the receiver, and he can override the receiver when he needs to pick up a bucketful of soil and transport it to another section of the field.

Fig. 1.5: Laser receiver

1.4.4 Control Panel: The control box accepts and processes signals from the machine mounted receiver. It displays these signals to indicate the drag bucket's positions related to the finished grade (Fig. 1.6). When the control box is set to automatic, it provides electrical output for driving the hydraulic valve. The control box mounts on the tractor within easy reach of the operator. The three control box switches are ON/OFF, Auto/ Manual Raise/Lower, which allows the operator to manually raise or lower the drag bucket.

Fig. 1.6: Control panel

1.4.5 Hydraulic Control System: The hydraulic system of the tractor is used to supply oil to raise and lower the levelling bucket. The oil supplied by the tractors hydraulic pump is normally delivered at 2000-3000 psi (Fig. 1.7). As the hydraulic pump is a positive displacement pump and always pumps more oil than required, a pressure relief valve is needed in the systems to return the excess oil to the tractor reservoir. If this relief valve is not large enough or malfunctions, damage can be caused to the tractors hydraulic pump. Wherever possible, it is advisable to use the external remote hydraulic system of the tractor as this system has a built-in relief valve where the oil is delivered directly from the pump to the solenoid control valve and an in line relief valve must be fitted before the control valve. The solenoid control valve,

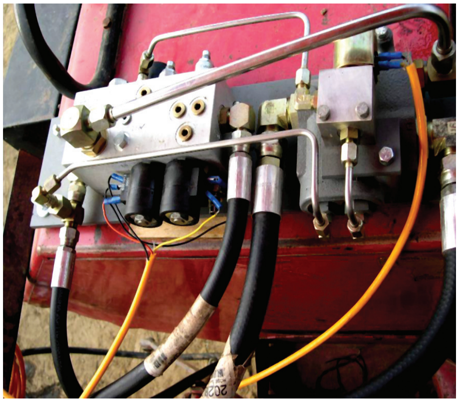

Fig. 1.7: Hydraulic control system

when supplied by the laser manufacturers has a built-in relief valve. The solenoid control valve controls the flow of oil to the hydraulic ram which raises and lowers the bucket. The hydraulic ram can be connected as a single or double acting ram. When connected as a single acting ram only one oil line is connected to the ram. An air breather is placed in the other connection of the ram to avoid dust contamination on the non-working side of the ram. In this configuration, the weight of the bucket is used for lowering. The desired rate at which the bucket raises and lowers will depend on the operating speed. The faster the ground speed the faster the bucket will need to adjust. The rate at which the bucket will raise and lower is dependent on the amount of oil supplied to the delivery line. Where a remote relief valve is used before the control valve, the pressure setting on this valve will change the raise/lower speed.

1.5 Operational aspects of laser land leveller

Laser controlled grading technology is currently the best method to grade a beam of light that can travel up to 700m in a perfectly straight line. The second part of the laser leveller systems is a receiver that senses the infra-red beam of light and converts it to an electrical signal. The electrical signal is directed by a control box to activate an electric hydraulic valve.

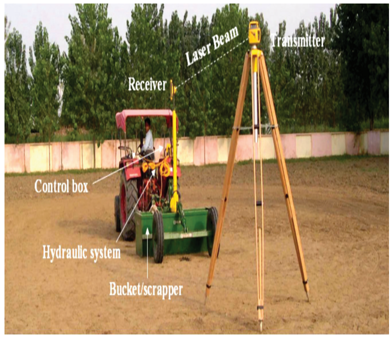

Fig. 1.8: Laser leveller in operation

This hydraulic valve raises and lowers the blade of a grader several times a second to keep it following the infra-red beam (Fig. 1.8). Laser levelling of a field is accomplished with a dual slope laser that automatically controls the blade of the land leveller to precisely grade the surface to eliminate all undulations tending to hold water. Laser transmitters create a reference plane over the work area by rotating the laser beam 360 degrees. The receiving system detects the beam and automatically guides the machine to maintain proper grade. The laser can be leveled or sloped in two directions. This is all accomplished automatically without operator touching the hydraulic controls.

1.6 Benefits of precision laser land levelling

Laser controlled precision land levelling helps in:

- Improving nutrient use efficiency with minimised leaching of available nutrients.
- Improving crop establishment, uniform growth, uniform distribution of water and nutrients.
- Improving uniformity of crop maturity.
- Approximately 3 to 5 % increase in cultivable area.
- Potential to increase water application efficiency up to 50%.
- Increase in yield of crops (wheat -15 %, rice -26 % & cotton -36 %).

- Control in emergence of salt affected patches in the soil.
- Approximately 25-35 % saving in irrigation water.
- Saves energy, labour and resources.

1.7 Limitations of laser levelling

- High cost of the equipment /laser instrument.
- Need for skilled operator to set /adjust laser settings and operate the tractor.
- More efficient for regularly sized and shaped field.

1.8 Precautions in laser levelling

- Correct assessment of average height of the field. Always drive the laser leveller from higher portions of the field to lower portions.
- The machine along with all its accessories should be thoroughly cleaned after operations and parked in a shed.
- The measuring equipments of the machine should always be refixed at the time of levelling a new field.
- The machine should be operated and repaired only by a trained person.

CHAPTER 2

Biogas Slurry

Food and nutrient security of the constantly increasing population can be ensured by enhancing the crop productivity on sustainable basis along with proper management of our natural resources i.e. the agricultural production base, especially land and water. Over exploitation and non judicious use of irrigation water, chemical fertilizers and agro chemicals have deteriorated soil health, water quality and the environment. In intensive cropping areas, organic carbon content of the soil is rapidly decreasing with overall deterioration of physical, chemical and biological properties of soil.

Biogas slurry proves to be a potential source to enhance the organic contents of the soil and to increase its water and nutrient holding capacity. The biogas technology is eco-friendly having dual benefit for the farmers in form of biogas as domestic fuel requirement and bio-slurry to enrich the soil with organic matter, thus leading to enhanced crop productivity. In developing countries expansion of this technology has been hindered because of lack of knowledge and the need for better economic initiatives, organized supervision, proper training and education.

Biogas slurry helps to bind soil particles together into aggregates. This improves the physical properties of the soil making it easier for root to develop and penetrate. Tillage becomes easier and soil becomes well drained. The binding effect also reduces wind and water erosion. With increase in organic matter of soil the water and nutrient retention capacity of soil is increases considerably. Organic matter also plays an important role because of its beneficial effects in supplying plant nutrients, enhancing the cation exchange capacity, improving soil aggregation and stabilizing its humus contents. Organic soil amendments support biological activities and also control root pathogens. Biogas slurry has proved to be high quality organic manure compared to FYM. Digested slurry have more nutrients, because in FYM, the nutrients are lost by volatilization (especially nitrogen) due to exposure to sun (heat) as well as by leaching. When fresh cow dung dries, approximately 30 to 50 per cent of the nitrogen escapes within 10 days. While nitrogen escaping from digested slurry within the same period amounts to only 10 to 15 per cent. Therefore, the value of slurry as fertilizer, if used directly in the field as it comes out of the plant, is higher than when it is used after being stored and dried.

2.1 Types of Biogas Plants

Considering the feeding method, three different types of Biogas plants can be distinguished:

2.1.2 Batch plants are filled once and then emptied completely after a fixed retention time. Each design and each fermentation material is suitable for batch filling, but batch plants require high labour input. As a major disadvantage, their gas-output is not steady.

2.1.3 Continuous plants are fed and emptied continuously. They empty automatically through the overflow whenever new material is filled in. Therefore, the substrate must be fluid and homogeneous. Continuous plants are suitable for rural households as the necessary work fits well into the daily routine. Gas production is constant, and higher than in batch plants. Today, nearly all biogas plants are operating on a continuous mode.

2.1.4 Semi batch plants: If straw and dung are to be digested together, a biogas plant can be operated on a semi batch basis. The slowly digested straw-type material is fed in about twice a year as a batch load. The dung is added and removed regularly.

2.2 Design of Biogas Plant

Throughout the world, a countless number of designs of biogas plant have been developed under specific climatic and socio –economic conditions. The performance of a biogas plant is dependent on the local conditions in terms of climate, soil conditions, the substrate for digestion and the availability of building material. The design must respond to these conditions. In areas with generally low temperatures, insulations and heating devices may be important. If bedrocks occur frequently, the design must avoid deep excavation work. The amount and type of substrate to be digested have a bearing on size and design of the digester and the inlet and out let construction. The choice of design will also be based on the building materials which are available reliably and at reasonable cost. The bio gas plants can be made of synthetic plastic, metals, bricks and cement concrete and bamboo.

Considering the construction, two most familiar types of biogas plants in developing countries are 1) Floating drum plants 2) Fixed - dome plants.

2.2.1 Floating drum plants: A floating drum plant consists of a cylindrical or dome shaped digester and a moving, floating gas holder, or drums. The gas –holder floats rather directly in the fermenting slurry or in a separate water jacket. The drum in which the biogas collects has an internal and/or external

Fig. 2.1: Floating drum plant

guide frame that provides stability and keeps the drum upright. If biogas is produced, the drum moves up, if gas is consumed, the gas-holder sinks back (Fig. 2.1).

Water Jacket floating–drum plants : Water–jacket plants are universally applicable and easy to maintain. The drum cannot get stuck in a scum layer, even if the substrate has high solids content (Fig. 2.2). Water–jacket plants are characterized by a long useful life and a more aesthetic appearance (no dirty gas holder). Due to their superior sealing of substrate (hygiene), they are recommended for use in the fermentation of night soil. The extra cost of the masonry water jacket is relatively modest.

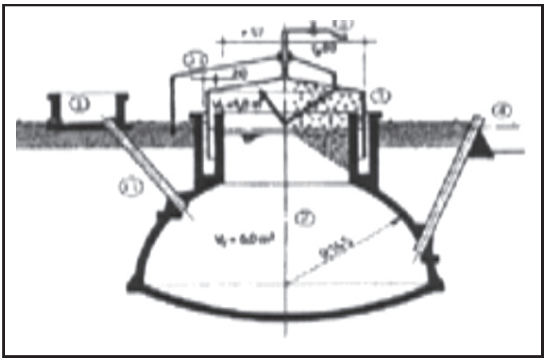

Fig. 2.2: Water jacket floating drum plants

Material of digester and drum : The digester is usually made of brick, concrete or quarry–stone masonry with plaster. The gas drum normally consists of 2.5 mm steel sheets for the sides and 2 mm sheets for the top. It has welded in braces which break up surface scum when the drum rotates. The drum must be protected against corrosion .Suitable coating products are oil paints synthetic paints and bitumen paints.

Guide frame : The side wall of the gas drum should be just as high as the wall above the support ledge. The floating drum must not touch the outer walls. It must not tilt, otherwise the coating will be damaged or it will get stuck. For this reason, a floating–drum always requires a guide. This guide frame must be designed in a way that allows the gas drum to be removed for repair. The drum can only be replaced by a balloon above the digester. This reduces construction costs but in practice problems always arise with the attachment of the balloon to the digester and with the high susceptibility to physical damage.

Types of floating – drum plants : There are different types of floating –drum plants .

- **KVIC model** with a cylindrical digester, the oldest and most widespread floating drum biogas plants from India.
- **Pragati model** with a hemisphere digester.
- **Ganesh model** made of angular steel and plastic foil.
- **Floating–drum** plants made of pre–fabricated reinforced concrete compound units.
- **Floating–drum** plants made of fibre-glass reinforced polyester.
- **Baroda model -** The Baroda plants combines the static advantages of hemispherical digester with the process –stability of the floating – drum and the longer life span of a water jacket plant.

Advantages: Floating –drum plants are easy to understand and operate. They provides gas at a constant pressure, and the stored gas –volume is immediately recognizable by the position of the drum. Gas –tightness is no problem, provided the gas holder is de-rusted and painted regularly.

Disadvantages: The steel drum is relatively expensive and maintenance–intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (up to 15 years; in tropical coastal regions about five years). If fibrous substance are used, the gas holder shows a tendency to get “stuck” in the resultant floating scum.

2.2.2 Fixed - dome plants : The cost of a fixed-dome biogas plant is relatively low. It is simple as no moving parts exist. There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected. The plant is constructed underground, protecting it from physical damage and saving space. While the underground digester is protected from low temperatures at night during cold seasons but sunshine in warm seasons take longer to heat up the digester. The day/night fluctuations of temperature in the digester positively influence the bacteriological processes. The construction of fixed dome plants is labour-intensive, thus creating local employment. Fixed-dome plants are easy to construct but construction work should be done by a well trained mason. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (Fig. 2.3).

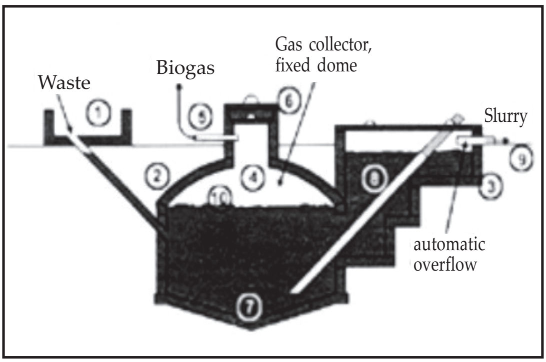

Fig. 2.3: Fixed - dome plants

Functions : A fixed dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gas –holder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced in to the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gas holder, the gas pressure is low.

Digester : The digester of fixed dome plants are usually masonry structures, of cement and ferro-cement. Main parameters for the choice of material are:

- Technical suitability (stability, gas – and liquid tightness).
- Cost – effectiveness.
- Availability in the region and transport costs.
- Availability of local skills for working with the particular building material.

Fixed dome plants produce just as much gas as floating – drum plants, if they are gas tight. However utilization of the gas is less effective as the gas pressure fluctuates substantially. Burners and other simple appliances cannot be set in an optimal way. If the gas is required at constant pressure (e.g. for engines), a gas pressure regulator or a floating gas –holder is necessary.

Gas Holder : The top part of a fixed –dome plant (the gas space) must be gas –tight. Concrete, masonry and cement rendering are not gas –tight. The gas space must therefore be painted with a gas –tight layer (e.g. Water –proofer', Latex or synthetic paints). A possibility to reduce the risk of cracking of the gas – holder consists in the construction of a weak – ring in the masonry of the digester. This "ring" is a flexible joint between the lower (water –proof) and the upper (gas-proof)part of the hemispherical structure. It prevents cracks that develop due to the hydrostatic pressure in the lower parts to move into the upper parts of the gas holder.

Types of fixed-dome plants

- **Chinese fixed-dome plant** is the archetype of all fixed dome plants. Several million have been constructed in China. The digester consists of a cylinder with round bottom and top (Fig. 2.4).
- **Janta model** was the first fixed-dome design in India, It is not constructed anymore. The mode of construction

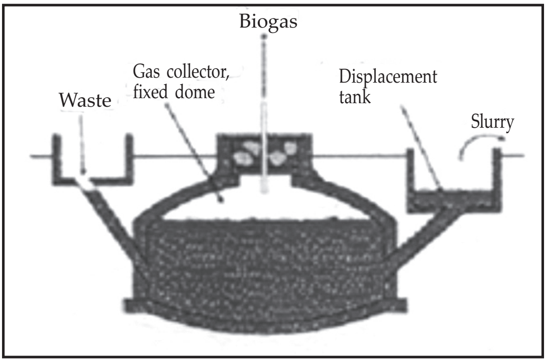

Fig. 2.4: Chinese fixed-dome plant

leads to cracks in the gasholder - very few of these plants had been gas-tight.

- **Deenbandhu,** the successor of the Janta model in India, with improved design of hemispheric digester was developed by AFPRO in early eighties. This is cheaper than Janta model. Its construction and maintenance cost is also less than Janta model (Fig. 2.5). It was designed on the pattern of fixed dome plant being constructed in China. This plant is 25-30% cheaper than KVIC model and the maintenance cost is almost negligible. This model has been approved by Ministry of Non –Renewable Energy resources for construction of biogas plants of capacity ranging from 1-6 m^3.

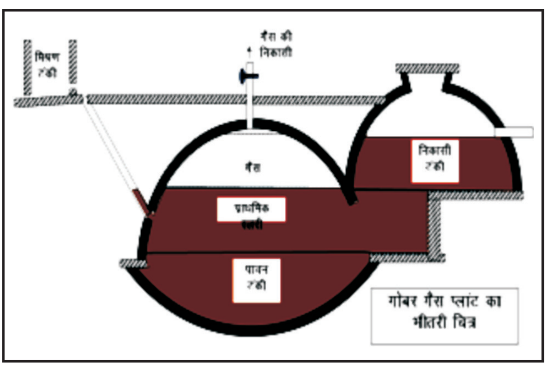

Fig. 2.5: Deenbandhu model

- **CAMARTEC model** has a simplified structure of a hemispherical dome shell based on a rigid foundation ring only and a calculated joint of fraction, the so-called weak / strong ring. It was developed in the late 80s in Tanzania. There are several other models but they are not very popular among farmers (Fig. 2.6).

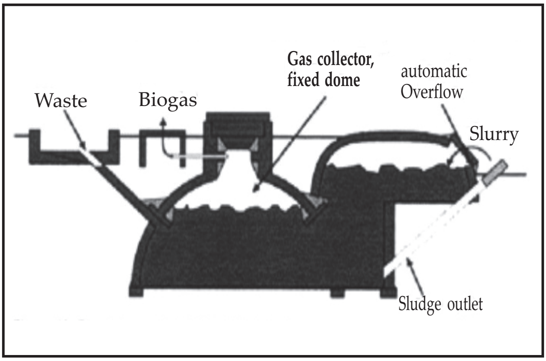

Fig. 2.6: CAMARTEC model

Advantages: Low initial costs and long useful life –spam; no moving or rusting parts involved; basic design is compact, saves space and is well insulated; construction creates local employment.

Disadvantages: Masonry gas-holders require special sealants and high technical skills for gas – tight construction; gas leaks occur quite frequently; fluctuating gas pressure complicates gas utilization; amount of gas produced is not immediately visible, plant operation not readily understandable; fixed dome plants need exact planning of levels; excavation can be difficult and expensive in bedrock.

2.3 Parts of Biogas Plants

2.3.1 Influent collecting tank : Fresh substrate is usually gathered in an influent collecting tank prior to being fed into the digester. Depending on the type of system, the tank should hold one to two days' substrate. An influent collecting tank can also be used to homogenize the various substrates and to set up the required consistency, e.g. by adding water to dilute the mixture of vegetable solids (straw, grass, etc.), or by adding more solids in order to increase the biomass. The fibrous material is raked off the surface, if necessary, and any stones or sand settling at the bottom are cleaned out before the slurry is admitted to the digester. The desired degree of homogenization and solids content can be achieved with the aid of an agitator, pump or chopper. A rock or wooden plug can be used to close off the inlet pipe during the mixing process. The size of the tank will depend on the size and material to be used. Any dairy farm waste should be kept for 36-48 hours in dung mixed water before feeding the same.

2.3.2 Inlet and outlet : The inlet (feed) and outlet (discharge) pipes lead straight into the digester at a steep angle. For liquid substrate, the pipe diameter should be 10-15 cm, while fibrous substrate requires a diameter of 20-30 cm. The inlet and the outlet pipe mostly consist of plastic or concrete. Both the inlet and the outlet pipe must be freely accessible and straight, so that a rod can be pushed through to eliminate obstructions and agitate the digester contents. The pipes should penetrate the digester wall at a point below the lowest slurry level (i.e. not through the gas storage). The points of penetration should be sealed and reinforced with mortar. The inlet pipe ends higher in the digester than the outlet pipe in order to promote more uniform flow of the substrate. In a fixed-dome plant, the inlet pipe defines the bottom line of the gas-holder, acting like a security valve to release over-pressure. In a floating-drum plant, the end of the outlet pipe determines the digester's (constant) slurry level. Inlet and outlet pipe must be placed in connection with brick-laying. It is not advisable to break holes into the spherical shell afterwards; this would weaken the masonry structure. Toilet can also be linked by a separate in let pipe of more than 15 cm diameter.

2.3.3 Digester : The digester consists of a hemispherical/ cylindrical structure with round bottom and top. No matter which design is chosen, the digester (fermentation tank) must meet the following four requirements (Fig. 2.7).

Fig. 2.7: Digester

- ***Water/gas tightness :*** Water tightness in order to prevent seepage and the resultant threat to soil and groundwater quality; gas tightness in order to ensure proper containment of the entire biogas yield and to prevent air entering into the digester (which could result in the formation of an explosive mixture). Even minor leakage may become the cause for failure of biogas plants. About 40-50% plants constructed in India during sixties and seventies failed due to such leakage problem. So all precautions need to be taken to ensure gas tightness
- ***Insulation :*** If and to which extent depends on the required process temperature, the local climate and the financial means. Heat loss should be minimized if outside temperatures are low, warming up of the digester should be facilitated when outside temperatures are high in day time. The plant location should be such that it receives good amount of sun light during winter. Inner surface of gas holder should have the coating of good quality paint.
- ***Minimum surface area*** keeps cost of construction to a minimum and reduces heat losses through the vessel

walls. A spherical structure has the best ratio of volume and surface area. For practical construction, a hemispherical construction with a conical floor is close to the optimum.

- *Structural stability* sufficient to withstand all static and dynamic loads, durable and resistant to corrosion.

Digesters can be made from any of the following materials:

Steel Vessels : Steel vessels are inherently gas-tight, have good tensile strength, and are relatively easy to construct (by welding). In many cases, a discarded steel vessel of appropriate shape and size can be salvaged for use as a biogas digester. Susceptibility to corrosion both outside (atmospheric humidity) and inside (aggressive media) can be a severe problem. As a rule, some type of anticorrosive coating must be applied and checked at regular intervals. Steel vessels are only cost-effective, if second-hand vessels (e.g. train or truck tankers) can be used. In steel vessel plant, cost of maintenance is high because timely cleansing and repair is necessary. In cold places the gas output of such plants is also affected because steel is a good conductor of heat. In such cases either insulation or heating system may be required to ensure proper functioning of the plant.

Concrete vessels : Concrete vessels have gained widespread acceptance in recent years. The requisite gas tightness necessitates careful construction and the use of gas-tight coatings, linings and/or seal strips in order to prevent gas leakage. Most common are stress cracks at the joints of the top and the sides. The prime advantage of concrete vessels is their practically unlimited useful life and their relatively inexpensive construction. This is especially true for large digesters in industrialized countries.

Masonry : Masonry is the most frequent construction method for small scale digesters. Only well-burnt clay bricks, high quality, pre-cast concrete blocks or stone blocks should be used in the construction of digesters. Cement-plastered/ rendered masonry is a suitable – and inexpensive - approach for building an underground biogas digester, whereby a dome-like shape is recommended. For domes larger than 20 m^3 digester volume, steel reinforcement is advisable. Masons who are to build masonry digesters have to undergo specific training and, initially, require close supervision. Such plants are ideal where labour is cheaply available. Such plants are easy to maintain and their gas out put is also good with little effect of change of temperature.

Plastics - Plastics have been in widespread use in the field of biogas engineering for a long time. Basic differentiation is made between flexible materials (sheeting) and rigid materials (PE, GRP, etc). Diverse types of plastic sheeting can be used for constructing the entire digesting chamber (balloon gas holders) or as a vessel cover in the form of a gas –tight "bonnet".

Sheeting made of caoutchouc (India rubber), PVC, and PE of various thickness and description have been tried out in numerous systems. The durability of plastic materials exposed to aggressive slurry, mechanical stress and UV radiation, as well as their gas permeability, vary from material to material and on the production processes employed in their manufacture. Glass –fibre reinforced plastic (GRP) digesters have proven quite suitable, as long as the in service static stresses are accounted for in the manufacturing process. GRP vessels display good gas – tightness and corrosion resistance. They are easy to repair and have a long useful life span. The use of sandwich material (GRP-foam insulation-GRP) minimizes the on –site insulating work and reduces the cost of transportation and erection.

2.3.4 Gasholders : Basically, there are three different designs of construction for gasholders used in simple biogas plants:

- **Floating –drum gas holders :** Most floating –drum gas –holders are made of 2-4 mm thick sheet steel, with the sides made of thicker material than the top in order to compensate for the higher degree of corrosive attack. Structural stability is provided by L-bar bracing that also serves to break up surface scum when the drum is rotated. A guide frame stabilizes the gas drum and prevents it from tilting and rubbing against the masonry. The two equally suitable and most frequently used types are:

i. An internal rod & pipe guide with a fixed (concrete-embedded) cross pole (an advantageous configuration in connection with an internal gas outlet).
ii. External guide frame supported on three wooden or steel lags.

For either design, substantial force can be necessary to rotate the drum, especially if it is stuck in a heavy layer of floating scum. Any gas – holder with a volume exceeding 5 m^3 should be equipped with a double guide (internal and external).

All grades of steel normally used for gas–holders are susceptible to moisture – induced rusting both in–and outside. Consequently, a long service life requires proper surface protection, including thorough de-rusting and de-soiling, primer coat of minimum 2 layers and 2 or 3 cover coats of plastic or bituminous paint.

The cover coats should be reapplied annually. A well – kept metal gas - holder can be expected to last between 3 and 5 years in humid, salty air or 8-12 years in a dry climate. Materials regarded as suitable alternatives to standard grades of steel are galvanized sheet metal, plastics (glass – fibre reinforced plastic (GRP), plastic sheeting) and ferro-cement with a gas – tight lining. The gas – holders of water – jacket plants have a longer average service life, particularly when a film of used oil is poured on the water seal to provide impregnation.

- **Fixed-dome gasholders:** A fixed-dome gas-holder can be either the upper part of a hemispherical digester or a conical top of a cylindrical digester (e.g. Chinese fixed-dome plant). In a fixed-dome plant the gas collecting in the upper part of the dome displaces a corresponding volume of digested slurry. The following aspects must be considered with regard to design and operation (Fig. 2.8):

Fig. 2.8: Fixed-dome gasholders

i. An overflow into and out of the compensation tank must be provided to avoid overfilling of the plant.

ii. The gas outlet must be located about 10 cm higher than the overflow level to avoid plugging up of the gas pipe.

iii. A gas pressure of 1 m WC or more can develop inside the gas space. Consequently, the plant must be covered sufficiently with soil to provide an adequate counter pressure and also save it from temperature fluctuations due to which cracking may develop.

Special care must be taken to properly close the man hole, which may require weighing down the lid with 100 kg or more. The safest method is to secure the lid with clamps. The Following structural measures are recommended to avoid cracks in the gas – holder:

i. The foot of the dome (gas- holder) should be stabilized by letting the foundation slab project out enough to allow for an outer ring of mortar.

ii. A rated break/pivot ring should be provided at a point located between 1/2 and 2/3 of the minimum slurry level. This is done in order to limit the occurrence or propagation of the cracks in the vicinity of the dome foot and to displace forces through its stiffening/articulating effect such that tensile forces are reduced around the gas space. Alternatively, the lowest point of the gas – holder should be reinforced by a steel ring or the whole gas- holder be reinforced with chicken mesh wire.

- **Plastic gas - holders:** Gas – holders made of plastic sheeting serve as integrated gas – holders, as separate balloon/bag-type gas-holders and as integrated gas – transport/storage elements. For plastic (sheet) gas-holders, the structural details are of less immediate interest than the question of which materials can be used.

2.3.5 Gas pipe, valves and accessories :

Biogas piping : At least 60% of all non-functional biogas units are attributable to defective gas piping. Utmost care has to be taken, therefore, for proper installation. For the sake of standardization, it is advisable to select a single size for all pipes, valves and accessories.

The requirements for biogas piping, valves and accessories are essentially the same as for other gas installations. However, biogas is 100% saturated with water vapor and contains hydrogen-sulphide. Consequently, no piping, valves or accessories that contain any amounts of ferrous metals may be used for biogas piping, because they would be destroyed by corrosion within a short time. The gas lines may consist of standard galvanized steel pipes. Also suitable (and inexpensive) is plastic tubing made of rigid PVC or rigid PE. Flexible gas pipes laid in the open must be UV-resistant.

Steel pipes : Galvanized steel water supply pipes are used most frequently, because the entire piping system (gas pipe, valves and accessories) can be made of universally applicable English/U.S. Customary system components, i.e. with all dimensions in inches. Pipes with nominal dimensions of 1/2" or 3/4" are adequate for small-to-midsize plants of simple design and pipe lengths of less than 30 m. For larger plants, longer gas pipes or low system pressure, a detailed pressure-loss (pipe-sizing) calculation must be performed. When installing a gas pipe, special attention must be paid to

i. Gas-tight, friction-type joints
ii. Line drainage, i.e. with a water trap at the lowest point of the sloping pipe in order to empty water accumulation
iii. Protection against mechanical impact.

2.4 Substrate and Management

Cattle dung is the most suitable material for biogas plants because of the methane producing bacteria already contained in the stomach of ruminants. The specific gas production, however, is lower and the proportion of methane is around 65% because of prefermentation in the stomach (Fig. 2.9).

Fig. 2.9: Substrate and management

Its homogenous consistency is favourable for use in continuous plants as long as it is mixed with equal quantities of water. Fresh cattle dung is usually collected and carried to the system in buckets or baskets. Upon arrival it is hand-mixed with about an equal amount of water before being fed into the digester. Straw and leftover fodder or hay is removed by hand in order to prevent clogging and reduce scum formation. Since most simple cow-sheds have dirt floors, the urine is usually not collected. When it is, it usually runs along the manure gutter and into a pail standing in a recess at the end of the gutter. The pail is emptied into the mixing pit – thereby replacing some of the mixing water - in preparation for charging the digester. Urine can considerably increase the gas production. A cemented stable floor, directly attached to the mixing pit, is the best solution to make optimum use of dung and urine and to save time for charging the digester. Liquid cattle manure, a mixture of dung and urine, requires no extra water. However, the simple animal housing found on most farms in developing countries normally does not allow the collection of all animal excreta. Hence, most of the urine with its valuable plant nutrients is lost.

2.5 Operation and Use of Biogas plant

The day-today operation of a biogas unit requires a high level of discipline and routine to maintain a high gas production and to ensure a long life-span of the biogas unit. Many problems in the performance of biogas plants occur due to user mistakes or operational neglect. Often, these problems can be reduced by

- Proper selection of bio gas plant site near to water and dung source, receiving ample sunshine during winter.
- Less complicated designs that are adapted to the substrate, the climatic conditions and the technical competence of the user,
- High-quality and user-friendly appliances,

- Design and lay-out of the biogas for convenient routine work,
- Proper training and easy access to advice on operation problems.
- Regular and proper feeding of the plant.
- Timely check –up and maintenance of pipe line and appliances.
- Weekly removal of water from trap point.
- Proper adjustment of appliances.

2.5.1 Feeding of the digester : In larger biogas units, the dung, urine and other substrate usually enter the plant by pipes, channels, belts or pumps. The available substrate has to enter the digester as soon as it is available to avoid pre-digestion outside the digester. The functioning of the feeding mechanisms has to be checked daily. Separators for unsuitable material have to be checked and emptied. The amounts of substrate fed into the digester may be recorded to monitor the performance of the biogas plant. Smaller plants in developing countries are fed by hand. The substrates often dung and urine, should be thoroughly mixed, plant residues should be chopped, if necessary. Obstructive materials like stones and sand should be removed from the mixing chamber. Filling work is further made easier by smooth concrete stable-floors and a minimized distance between the stable and the plant (Fig. 2.10).

Fig. 2.10: Feeding of the digester

2.5.2 Controlling the overflow : A special problem of small scale fixed dome plants is the clogging up of the overflow point. This can lead to over-pressure (the hydraulic pressure increases with the slurry level in the expansion chamber) and to clogging of the gas outlet if too much slurry flows back into the digester. The overflow point should, therefore, be checked and cleaned daily.

2.5.3 Biogas - Sludge Management

- **Sludge storage :** To retain the maximum fertilizing quality of digested slurry, i.e. it's nitrogen content, it should be stored only briefly in liquid form in a closed pit or tank and then applied on the fields. Preferably, it should be dug into the soil to prevent losses on the field. Sludge storage is normally affected according to one or the other of the following three techniques

- **Liquid storage :** The effluent outlet of the biogas system leads directly to a collecting tank. Loss of liquid due to evaporation or seepage must be avoided. Just before the sludge is needed, the contents of the tank is thoroughly agitated and then filled into a liquid manure spreader or, if it is liquid and homogenous enough, spread by irrigation sprinklers. The main advantage of liquid storage is that little nitrogen is

Fig. 2.11: Storage of slurry

lost. On the other hand, liquid storage requires a large, waterproof storage facility entailing a high initial capital investment (Fig. 2.11).

- **Drying :** It is only possible to dry digested sludge as long as the rate of evaporation is substantially higher than the rate of precipitation. The main advantage of drying is the resultant reduction in volume and weight. Drying can also make the manual spreading easier. The cost of constructing shallow earthen drying basins is modest. On the other hand, drying results in a near-total loss of inorganic nitrogen (up to 90%) and heavy losses of the total nitrogen content (approx. 50%).

- **Composting :** Nitrogen losses can be reduced by mixing the digested sludge with organic material. As an additive to crop residues for composting, biogas sludge provides a good source of nitrogen for speeding up the process. At the same time it enriches the compost in nitrogen, phosphorus and other plant nutrients. Furthermore, the aerobic composting process, by it's temperature, effectively destroys pathogens and parasites that have survived the anaerobic digestion treatment. The ready-made compost is moist, compact and can be spread out by simple tools. With most available transport facilities in developing countries, it is easier to transport than liquid manure.

2.6 Factors affecting efficiency of Biogas Plant

i. **Climatic temperature** – optimum temperature: 35^0c

ii. **Carbon Nitrogen (C/N) ratio of the matter to be digested**, optimum value-25:1 to 30:1

iii. **pH value of the matter to be digested optimal**-7-8

iv. **Dilution and consistency of Input:** For optimum anaerobic fermentation, normally 8 -10 per cent total solids in feed is required which can be achieved by making slurry of fresh cattle dung in water in ratio 1:1.

v. **Loading rate:** Amount raw material fed per day per unit of digester capacity. A daily loading of 16 kg of volatile solids per m^3 of digester capacity produces 0.04-0.074 m^3 of gas per kg of cattle dung fed.

vi. **Hydraulic Retention time-** For digesters operating in countries of tropical region like India, HRT is usually taken as 40-60 days.

vii. **Additive supplements-** Some mineral ions and presence of NH_4 from 50 to 200 mg/litre stimulates the growth of anaerobic microbes where as higher concentration of these ions, alkali detergents, antibiotics and organic solvents inhibit the activity of methane producing bacteria.

viii. **Agitation or mixing of digester contents:** It significantly improves the fermentation.

2.7 Security precautions

When operating a biogas plant special attention has to be paid to the following precautions:

- Breathing in biogas in a high concentration and over longer periods of time can cause poisoning and death from suffocation. The hydrogen sulphide contents of biogas are highly poisonous. Unpurified biogas has the typical smell of rotten eggs. Purified biogas is odourless and neutral. Therefore, all areas with biogas operating appliances should be well ventilated. Gas pipes and fittings should be checked regularly for their gas-tightness and be protected from damage. Gas appliances should always be under supervision during operation. Everybody dealing with biogas, in particular children should be instructed well and made aware of the potential dangers of biogas.

- After emptying biogas plants for repair, they have to be sufficiently ventilated before being entered. Here the danger of fire and explosion is very big (gas/air mixture!). The so-called chicken test (a chicken in a basket enters the plant before the person) guarantees sufficient ventilation.
- Biogas in form of a gas-air mixture with a share of 5 to 12 % biogas and a source of ignition of 600°C or more can easily explode. Danger of fire is given if the gas-air mixture contains more than 12 % of biogas. Smoking and open fire must therefore be prohibited in and around the biogas plant.
- The initial filling of a biogas plant poses a particular danger, when biogas mixes with large empty air-spaces. A farmer may want to check with an open flame how full the plant is already and cause an explosion.
- The digester of a biogas plant and the slurry storage facilities should be built in such a way that neither persons nor animals are in danger of falling into them.
- Moved and movable parts should have a protective casing to avoid catching persons or animals.
- Appliances operating on biogas normally have high surface temperatures. The danger of burning is high, in particular for children and strangers. A casing of non heat- conducting material is advisable.
- The mantle of the gas lamp is radioactive. The mantle has to be changed with utmost caution. Especially the inhalation of crumbling particles must be avoided. Hands should be washed immediately afterwards.
- The piping system can form traps on the farm compound. As much as possible, pipes should be laid some 30 cm underground. Pits for water traps, gas meters, main valves or test-units should be caged by a concrete frame and covered with a heavy concrete lid.

CHAPTER 3

Raised Bed Technology

Almost all the cereal and vegetable crops have been conventionally planted by farmers in narrow spaced rows on flat surfaces or broadcast and irrigated by flood irrigation within check basins and border strips. Such flood irrigation results in low water use efficiency and depletion of soil nutrients. It also causes crusting of the soil surface. The weeds infestation is also enhanced and the crops have to compete with them for water, nutrient and sunlight.

Raised bed-planting system with a number of defined rows (usually two to four rows) planted on top of the bed with furrow irrigation offers great potential to avoid such wastage of water and soil nutrients. The technology can also reduce water logging stress through improved surface drainage, and the opportunity to diversify for the crops sensitive to water logging Weeds are also suppressed. Raised beds enable crop flexibility, rapid response to market opportunities and intercropping along with improving soil organic matter status. Use of raised beds increases the

Fig. 3.1: Raised bed in wheat

productivity, profitability and sustainability of cropping systems, principally through improving soil structure, drainage, direct drilling of crops and reducing irrigation requirements through furrow irrigation (Fig. 3.1).

The raised bed planting system is known with other names like Furrow Irrigated Ridge-till Bed-planting System (FIRBS), bed planting, ridge planting etc. This system is suitable for the crops like wheat, maize, cotton, ground nut and many other crops including vegetable and floriculture crops. In the crop sequences of wheat- soybean/maize/cotton, a system of reduced tillage can also be followed whereby sowing can be done directly on the same beds without field preparation. However, in rice - wheat cropping system, after rice a fine seed bed preparation is done followed by sowing of wheat on raised beds. Raised bed system is also popular in vegetable crops like potato, carrot, onion and other vegetables.

The sowing on raised beds is done with the help of the raised bed planter in lines on closer spacing of 15 cm. The raised bed technology helps keep soil warmer. The soil of the raised bed is elevated above ground level, allowing the sun and air to warm it faster. This technology facilitates early planting, and better seed germination, especially in colder climates particularly in north Indian conditions. It suppresses weed infestation due to closer plant spacing thus, decreasing the use of weedicides. The better aerations in the raised beds help better root and shoot development of the crop. The access in the field crop is easy which facilitates intercultural operations like manual weeding, spraying of fertilizers, herbicides as well as pesticides. The ridge and furrow system also facilitates good drainage because the soil is above ground level and heavy rains drain off much better. The fertilizer use efficiency is also enhanced and crops come up better in comparison to conventional sowing. Saving of water, fertilizer, seed and other crop inputs make its use more beneficial. In addition, movement of worker engaged in field works becomes easy.

3.1 Potential of raised bed planting system

Change over from growing crops in flat to ridge-furrow system of planting crops on raised bed alters the crop geometry and land configuration, offers more effective control over irrigation and drainage as well as their impacts on transport and transformations of nutrients, and rainwater management during the monsoon season. In furrow irrigated raised bed (FIRB) system, water moves horizontally from the furrows into the beds (subbing) and is pulled upwards in the bed towards the soil surface by capillarity, evaporation and transpiration, and downwards largely by gravity. In determining the dimensions of the beds, factors such as spacing between tractor tyres, soil types, rainfall and groundwater conditions, salinity and irrigation water quality and requirements of crops grown in rotation are of prime importance.

For developing a permanent system of bed planting, factors like irrigation and fertilizer management, crop residue management, inter-tillage and weed management must be considered together. For major soil types (sandy loam to loam soils) and crops (inter-row crop spacing requirement) grown in the IGP, ridge-furrow system, of 67cm width (top width of bed-37cm; and of furrow-30cm) is often considered appropriate. On the raised beds, two rows of rice, wheat,

Fig. 3.2: Sugar - cane plantation in wheat

maize or chickpea are generally grown. Yields with 2 and 3 rows of wheat per bed are comparable, but lodging is greater with 3 rows per bed. It is advantageous to plant on beds a single row of pigeon pea or intercropped wheat/mustard with furrow planted sugarcane (Fig. 3.2). For effective weed control, choice of crop cultivars that cover the surface early in the season is of great importance. Crop cultivars are known to vary significantly in their performance on FIRB. Efforts are in progress to identify appropriate cultivars in rice, wheat and other crops which are better suited for raised bed planting system.

3.2 Technical details of the technology

3.2.1 Bed planting : The sowing on raised beds is done with the help of the raised bed planter. The machine has adjustable blades for making raised beds of different widths and heights that can be adjusted by the shifting of blades on the frame and roller on the rear. It has seed-cum-fertilizer drilling mechanism for sowing one, two or three rows on each bed (Fig. 3.3).

Fig. 3.3: Bed planter

The planter makes two beds at a time. The width of beds can also be adjusted from 65-70 cm. The planter is fitted with knife type tines so that it can also be used for sowing of other crops. The cost of the machine ranges Rs. 30,000-80,000 depending upon the attachments. This system is often considered more appropriate for growing high value crops that are more sensitive to temporary water logging stress. Farmers have started raising crops such as cotton, maize-soybean and wheat on the raised beds. However, the practice of growing rice, the major water-using crop in rice-wheat systems, raised bed planting of crops may be particularly advantageous in areas where groundwater levels are falling and herbicide-resistant weeds are becoming a problem. This tillage and crop establishment option also facilitates crop diversification and intercropping of wheat with chickpea/ sugarcane, Indian-mustard with sugarcane, maize with potato, mint with wheat, rice with soybean, and pigeon pea with sorghum or green gram. Raised bed planting machine with ancillary attachments for drip pipe laying and mulch film laying along with hole punching facilities makes the system more useful for raising healthy vegetable crops like tomato, onion, brinjal, chillies etc. with highly improved water use efficiency and increased yield (Fig. 3.4).

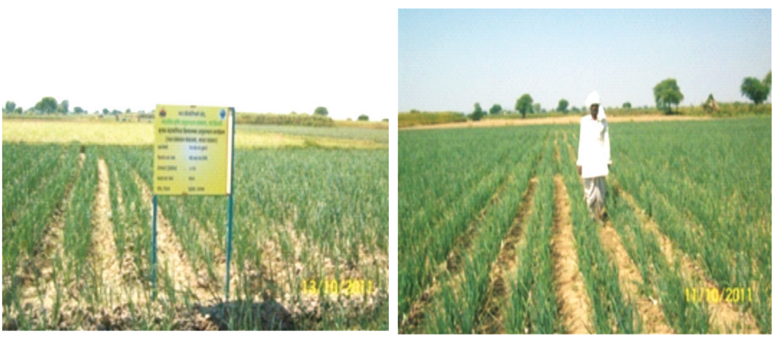

Fig. 3.4: Kharif onion on raised bed in farmers field

3.2.2 The number of rows planted : The number of rows planted/holes punched per pass of the machine is directly related to how many furrow openers it has. Machines can be classified as single row, five row, 40 row, etc, depending on the number of furrow openers. On multi-row machines, the furrow openers are typically uniformly spaced across the full width of the machine.

3.2.3 Plant population and spacing requirements: The plant population (i.e. the number of established plants/ha) influences the degree to which competition influences crop establishment. Many factors have to be considered when determining the optimum population and the spacing (i.e. the distance between rows of plants and the spacing of plants within a row) for a particular crop. The factors affecting potential yield include climatic conditions, time of planting, soil type and soil moisture status. Other factors to be considered relate to the ease of performing cultural practices. For example, row spacing may affect the ease of inter-row cultivation and harvesting. Populations and row spacing may affect weed growth and control, the degree of crop lodging, the size of the seed heads, etc.

3.2.4 Cultivation : To conserve bed shape and benefit from improvements of soil structure, it is desirable to use direct drilling whenever possible on raised beds (i.e. adhere to a permanent raised bed system). Direct drilling is a proven method of achieving good seed germination, plant establishment and growth in most stubble situations. Cultivation should only be considered when renovating the beds, or adding and incorporating products such as gypsum, farm yard manure poultry manure or lime.

3.2.5 Bed shape: Difficulties such as uneven cultivation depth, inaccurate bed forming and presence of underground rocks can make the beds and furrows uneven in height. As a result of sowing and other operating machines such as harvesters with tyres wider than the furrow, soil fall off the shoulders into the furrows and bed become very rounded. Under such conditions using seeders with normal rigid undercarriages and tine assemblies' results in uneven sowing depth, especially on the bed shoulders.

3.2.6 Soil structure : Raised bed controlled traffic systems greatly improve soil structure. Soil properties such as slaking, dispersion and bulk density are all decreased while water infiltration is increased (SFS 2000). The loose and friable nature of the soils can make good soil seed contact hard to achieve. Firming the seed bed after sowing will enhance the soil seed contact and improve seed germination and plant establishment.

3.2.7 Run-off from bed tops : The rounding of beds also accelerates water run- off, particularly from the bed shoulders. Grooving the beds in the direction of the bed using water harvesting furrows, usually formed with press wheels, can greatly help retain this valuable moisture

3.2.8 Nutrient loss from paddocks : One option to minimize nutrient loss with run-off leaving the field is to sow the furrows between the beds with crop. Especially in drier seasons these furrow-planted crops will contribute to overall yield, and crop plants growing in sown furrows will also compete with weeds.

3.3 Raised Bed Planter

The machine has adjustable blades for making raised beds of different widths and heights that can be adjusted by the shifting of blades on the frame and roller on the rear. It has seed-cum-fertilizer drilling mechanism for sowing one, two or three rows on each bed. The planter makes two beds at a time. The width of beds can also be adjusted from 65-70 cm. The planter is fitted with knife type tines so that it can also be used for sowing of other crops. The benefits of the machine are savings in cost of seed (25%) fertilizer (25%), and irrigation water (35%). The machine is particularly useful for farmers for conservation of irrigation water and other critical inputs and helpful in enhancing crop yield. With its effective field capacity of 0.2 ha per hour. The machine with its effective field capacity of 0.2 ha per hour can be operated with a tractor of 35-40 hp. commercially available machines cost up to Rs. 40,000- 80000 per unit depending upon attachments and other ancillary provisions like drip pipe laying, mulch film laying and hole punching facilities (Fig. 3.5).

Fig. 3.5: Raised bed planter operation in field

3.4 Advantages

- Management of irrigation water is improved.
- Bed planting facilitates irrigation before seeding and thus provides an opportunity for weed control prior to planting.
- Plant stands are better.
- Weeds can be controlled mechanically, between the beds, early in the crop cycle.

- Wheat seed rates are lower.
- After wheat is harvested and straw is burned, the beds are reshaped for planting the succeeding soybean crop. Burning can also be eliminated.
- Herbicide dependence is reduced, and hand weeding and roguing is easier.
- Less lodging occurs.
- Wheat raised in small and broad beds (Fig. 3.6).
- 50% saving in seed 30-40% saving in water.

Fig. 3.6: Wheat in raised bed technology

- Higher yields through more grains/spike and increased 1000-grain weight.
- reduction in drudgery.
- facilitates mechanical weeding by tractor.
- offers opportunity for last irrigation at grain filling stage.
- avoids temporary water logging problems.
- allows subsurface basal and top dressing of fertilizer.

- Reduces N losses & promotes rain-water conservation.
- Irrigation water management more efficient and less labour intensive with the use of furrows, compared to the traditional flood irrigation system.
- Bed Planting of wheat also makes it possible to reduce tillage and manage crop residues by reshaping and reusing the same beds without any tillage on the top of the bed.
- Paddy sown on raised beds reduces unproductive evaporation losses of water.

3.5 Precautions for Raised Bed Planting in Unfavorable and Marginal Environments

Alkali soils having high exchangeable sodium are slowly permeable. These soils need to be amended with gypsum, iron-pyrite and or other acid formers and leached before making raised bed. Gypsum should be mixed in surface 10cm layer of alkali soils and reaction products leached for several days.

3.5.1 Pest problems : A range of potential problems can occur when crops are grown on raised beds, and the potential damage caused by some pests and diseases may be different or more of a risk compared with crops grown 'on the flat'. Such problems need to be monitored and care-fully managed. A few examples include:

Rodents Mice can thrive in the dry friable soil of raised beds but this is a problem to watch out for on raised beds.

Disease The friable, well-aerated soils in raised beds have many advantages but they may stimulate some soil fungi, such as rhizoctonia, to be more of a problem.

Insects Many insects such as false wireworms thrive in well-drained and well-structured soils, as in raised beds.

Slugs Due to the use of mulch and consequent moister conditions in the furrows, slugs may become an increased problem in raised bed crop.

CHAPTER 4

System of Rice Intensification (SRI)

Traditional paddy cultivation of keeping the crop flooded with water for major crop period leads to low crop productivity / unit of irrigation water. Deep standing water in paddy field does not allow access of oxygen to roots, and more over results in increased methane release, a green house gas responsible for global warning. Farmers often have a wrong notion that they can boost their paddy yields by planting paddy plants more densely. Generally, for having a dense crop stand, three or more plants per hill from 25-35 days nursery are transplanted together in a clump at closer spacing of 10x15cm / 10x10cm / 10x20 cm in zigzag manner. These 25-35 days old seedling do not produce higher number of healthy effective tillers. The close planting common in traditional rice cultivation could be considered anti-tillering rice cultivation. The closely planted seedling do not get enough space for their root and shoot development on the one hand and on the other also block free flow of air.

The productivity enhancement in rice has recently been a great concern to agricultural researchers and policy makers. The System of Rice Intensification (SRI) has been found as a potential technology with dual advantage of productivity enhancement and resource conservation. In SRI 9-14 days young healthy seedlings are transplanted at 25x25 or 30x30 cm spacing in square pattern (Fig. 4.1). Only one healthy plant having sound roots is transplanted at one place. The plant get enough space for its root and shoot development and such plant bear good number of healthy effective tillers. The competition for light, air and nutrients is minimum among the crop plants as they get enough space for their development.

Fig. 4.1: Different Crop stages of rice under SRI

A thin layer of water 2 to 3 cm depth is maintained uniformly for 10 days for proper establishment of seedlings. After that, crop is irrigated as per the requirement under SRI to maintain proper moisture in soil. In this way, irrigation requirements of the crop can be reduced by 40-50 %.

The success of SRI is primarily dependent upon raising healthy and robust nursery which should be ready within 9-14 days of sowing. Care should be taken in uprooting the healthy seedling with minimum damage to the root system. In SRI, transplantation is carried out carefully and early, when 9 to 14 days old seedlings have only two leaves. It should be done very soon after removing the seedlings from the seedbed and within 15 to 30 minutes after the tiny plants have been gently uprooted. The tiny roots should be placed horizontally in the soil so that the tip of the root can easily resume its downward growth. In this way the plant will establish soon and will start to grow again within a few hours. The plants have time to adjust to their new environment before the first tiller starts to grow. In SRI at the beginning of tillering, there is still not much vegetative growth and the plant only requires a small amount of water. Subsequently, when the root system has been developed well, 3 or 4 days of superficial dryness should not cause alarm even if some cracks develop in the field. During growth period of the crop irrigation will only be needed if rainfall is inadequate and such irrigation should be applied in moderate amounts and at favorable times, preferably in the morning hours or late evening (Fig. 4.2). Irrigation should be avoided during noon, when it is too hot.

Fig. 4.2: Bumper SRI crop

Only a thin layer of water above surface or saturation condition is sufficient without any adverse effect on grain yield. For managing weeds and proper aeration hoeing with the help of conoweeder or wheel hand hoe may be done twice at 15 and 35 days after transplanting.

The success of SRI is based on the synergetic development of both the tillers and sound root system. With vigorous root growth and their better access to the nutrients and water, the overall vegetative development of the crop is enhanced resulting in more photosynthesis. Thus, the overall health of the crop is improved and plants are more resistant to attack of pests and diseases. Moreover, the number of effective tillers per plant is increased with full size development of grains in the spikes. In SRI, use of organic sources of nutrients could help achieve levels of production that could not be obtained using conventional practices applying inorganic fertilizers. However, if the available quantity of organic manures is not sufficient, inorganic fertilizers must be given in balanced dose on soil test basis, to realize the good yield.

4.1 Essential Steps for SRI

The first and foremost requirement of Successful System of Rice Intensification is proper raising of healthy nursery. For raising healthy and vigorous seedling a suitable seed bed of size 600 m^2 for transplanting nursery to 1 ha field should be prepared properly only after adding sufficient quantity of recommended dose of nitrogen, P_2O_5, K_2O and $ZnSO_4$@6.0,3.0,3.0kg and 600gm through urea, single super phosphate, muriate of potash and zinc sulphate respectively along with well decomposed Farm Yard Manure/Biogas Slurry. A three inch thick layer of such F.Y.M. should be mixed in top 3 inch upper layer of soil about 20-25 days before sowing the seeds. After adding the F.Y.M in the soil the seed bed should be irrigated twice so that the weed seed present in soil/manure can germinate and are destroyed in the process of seed bed preparation before sowing of seed. The use of sufficient quantity of F.Y.M. will not only improve the soil physical, biological and chemical properties but also supply required quantity of nutrients to the plants and plant growth will be much better with sound root development in loose soil. Following precautions will ensure healthy nursery.

4.1.1 Nursery on Raised Beds : It is always advisable to raise nursery on raised beds. In a well prepared paddy seed bed, raised beds of 1.0 m width and 10 m length should be prepared. Around these beds 30-40 cm drainage cum irrigation channels are prepared. On these nursery beds 1:1 soil: decomposed FYM mixture is spread to 4-5 cm thickness (Fig. 4.3).

Fig. 4.3: Healthy nursery grown on raised bed

4.1.2 Selection of variety : To realize full potential of SRI, it is important to select good paddy variety which has characteristic of profuse tillering (Fig. 4.4).

Fig. 4.4: Profuse tillering under SRI

4.1.3 Seed Quality and Treatment : Good quality healthy seed @6kg/ha should be used for raising nursery for SRI. It should be soaked for 24 hrs in a 10 litre water solution having 20-25 gm bavistin + 2gm streptcycline. Such seed treatment ensures healthy seedling.

4.1.4 Seed Sowing : Treated seed is incubated in moist gunny cloth for another 24 hour for sprouting. Nursery beds are irrigated preferably using sprinkling /fountain. Sprouted seeds are sown in horizontal rows on nursery beds. After sowing the seeds, again 1:1 soil-FYM mixture is spread in a thin layer of 1-2 cm. After sowing, nursery beds are again irrigated.

4.1.5 Regular watering : Regular irrigation in to the channels formed around the nursery beds is provided preferably in the mornings /evenings for maintaining moist condition in nursery beds. Sprinkling of water using fountain is also done as and when required. These practices are aimed at better aeration as well as avoiding the flooding of nursery bed. Weeding if required is done twice during the period.

4.2 Preparation of the field for transplantation:

The field should be irrigated, ploughed with tractor-drawn disc plough, followed by harrowing. The field should be properly levelled preferably with laser leveller (Fig. 4.5). After irrigation, when the soil reaches to tilth condition, the field

Fig. 4.5: A laser levelled field with uniform water level

should be ploughed with disc plough. FYM@5t/ha should be incorporated at second ploughing using a harrow. Puddling operation may be done twice using wheel mounted tractor drawn puddler. A uniform basal dose of 40 kg P_2O_5 ha^{-1} through single superphosphate, 30 kg K_2O ha^{-1} through muriate of potash and 15 kg ha^{-1} of zinc sulphate ($ZnSO_4$) is applied during second puddling and mixed well with soil. Field is demarcated into plots and channels are made which serve the purpose of both irrigation and drainage.

4.3 Early and careful transplanting

Water should be drained out of the field at the time of transplanting. Healthy seedlings (10-12 days old) are uprooted gently in such a way that roots are not damaged (Fig.4.6).

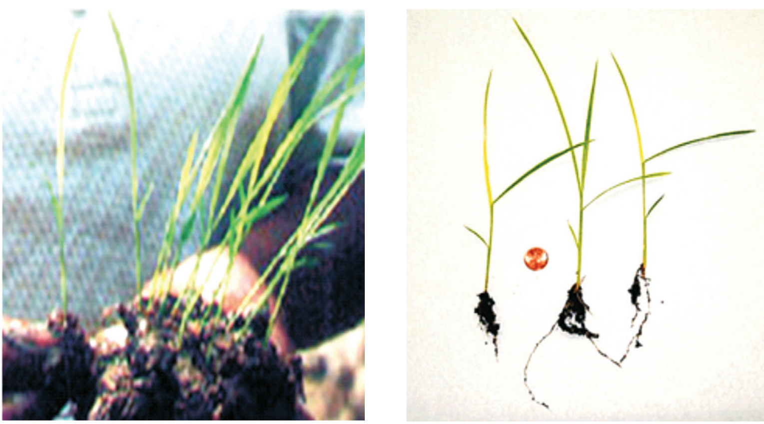

Fig. 4.6: Healthy seedling (12 days old-2 leaves stage)

Transplanting should be done in early morning or late evening hours as early as possible after removing the seedlings from the seed bed preferably within 15 to 30 minutes of uprooting. The tiny roots of the seedling should be gently plugged in the soil for minimizing the trauma during transplanting. Single seedling is planted in a square pattern at a spacing of 25cm x 25cm or 30cm x 30 cm. A field size rope well demarcated at equal lengths of 25cm / 30cm and held straight along field facilitates proper transplanting in line and at equal distance.

4.4 Gap filling

Gap filling may be done wherever seedlings fail to establish. For this purpose some SRI-nursery seedlings are kept along side of the channels at the time of transplanting. For gap filling, seedlings along with soil intact roots should be used. Gap filling will help to ensure proper crop stand for higher yield (Fig. 4.7).

Fig. 4.7: General view of rice field under SRI

4.5 Irrigation

Only a thin layer of water above surface or saturated condition is required for proper establishment of seedlings. After that, crop is irrigated only as per the requirement under SRI to maintain proper moisture in the field. The care is taken that the field is kept moist and not flooded (Fig. 4.8). Irrigation should be applied in moderate amount preferably during morning or late evening hours when it is not too hot.

Fig. 4.8: A very thin layer of water is sufficient for irrigation of SRI field

4.6 Weeding and intercultural operations

Whatever the crop, early weeding is always important for a good return. In rice, where traditional weeding methods are used, hand weeding is usually done one and a half months after transplanting. This is far too late for two important reasons. Not only are weeds replacing half the expected harvest by this time, but farmers also lose the opportunity to have good aeration in the soil for easy availability of oxygen to roots. Aeration of soil by weeding may be even more important in rice cultivation than the removal of weeds. However, hand weeding is labourious and cumbersome involving lot of drudgery. In SRI, with wider spacing simple mechanical push-weeders like wheel hand hoe or cona weeders can be used which require less labour to avoid drudgery (Fig. 4.9).

Fig. 4.9: Weed incorporation and soil churning

Moreover, these weeders churn up the soil helping in aeration as well as incorporating the weeds in soil adding as organic manure after decomposition.

Two weeding at 15 and 30 days after transplanting are sufficient for weed control in the SRI crop and for improvement of physical, chemical and microbial properties of the soil.

4.7 Advantages of SRI

- Saving on seed, as the seed requirement is significantly less.
- Saving of irrigation water as there is no need of ponding of water.
- Withstand short gap on water availability due to unavailability of electric supply.
- Saving on chemical fertilizers, pesticides etc. due to lesser infection of diseases and pests
- More healthy and quality rice due to use of organic manures.
- Higher yield due to profuse tillering, more effective tillers and healthy grains (Fig. 4.10).

Fig. 4.10: Scientists inspecting Rice field under SRI

4.8 Constraints of SRI

- Higher labour requirement for raising of nursery in rows on raised bed.

- Careful uprooting of younger seedlings from nursery and planting on the field require more labour.
- Requires levelled field condition to maintain uniform thin layer of water on the soil surface.
- Displacement of seedlings in the event of heavy monsoon rains just after transplanting.

5

CHAPTER

Micro Irrigation

India's average annual rainfall is about 120 cm. Due to the spatial and temporal distribution of rainfall one-third of the country is always under threat of drought. Generally under surface irrigation methods, only less than one half of the water released is utilized by the plant. A good part of the applied water is lost in conveyance, application, runoff and evaporation. Accordingly, the efficiency of surface irrigation methods is low. Micro irrigation systems (sprinkler, drip and micro sprinkler) offer possibilities of achieving higher efficiencies of water use through controlled water distribution. In micro irrigation systems water is applied more frequently which in turn reduces the moisture stress to the plants and thus enhances the crop growth.

5.1 Drip Irrigation

Drip irrigation is a method of water application for irrigating plants at the root zone through emitters fitted on a network of pipes (mains, sub-mains and laterals). Well designed drip system would provide uniform, equal and adequate water to all plants in the field at a higher level of irrigation efficiency.

The main advantage of drip irrigation system is its high degree of control on water application. Drip irrigation provides a large number of irrigating points per unit area that result in better uniformity of water application. Drip irrigation thus maintains uniform moisture content in the soil throughout the cropping period.

Drip irrigation can be used for most crops, such as:

Orchard crops Grapes, Banana, Pomegranate, Orange, Citrus, Tamarind, Mango, Fig, Lemon, Custard Apple, Sapota, Guava,

Fig. 5.1: Orchard crop under drip irrigation

Pineapple, Coconut, Cashew nut, Papaya, Aonla, Litchi, Watermelon, Muskmelon etc (Fig. 5.1)

Vegetables Tomato, Chilly, Capsicum, Cabbage, Cauliflower, Onion, Okra, Brinjal, Bitter gourd, Bottle gourd, Ridge gourd, Cucumber, Peas, Spinach, Pumpkin etc. (Fig. 5.2)

Cash crops Sugarcane, Cotton. Arecanut, Strawberry etc.

Fig. 5.2: Vegetables under drip irrigation

Flowers Rose, Carnation, Gerbera, Anthurium, Orchids, Jasmine, Lily, Mogra, Tulip, Dahilia, Marigold etc.

Plantation Tea, Rubber, Coffee, Coconut etc.

Spices Turmeric, Cloves, Mint etc.

Oil seed Sunflower, Oil palm, Groundnut etc

Forest crops Teakwood, Bamboo etc.

5.1.1 Types of drip irrigation systems

5.1.1.1 ***Surface Drip Irrigation System :*** In this system, the drippers and the lateral lines are laid on the soil surface. In this system, water is applied to the soil near the root zone of the plants (Fig. 5.3). The system applies water slowly under

Fig. 5.3: Surface drip system

pressure to help maintain the soil moisture within the desired range of plant growth. The volume of soil wetted by surface drip irrigation is much less than that wetted by surface irrigation methods.

5.1.1.2 ***Subsurface Drip Irrigation System :*** In this system, the laterals and the drippers are installed below the soil surface and water is applied slowly through drippers (Fig. 5.4). The most commonly used systems are Bi-wall, Typhoon, T- tape and cane wall system. These systems are mostly used for irrigating row crops.

Fig. 5.4: Subsurface drip system

5.1.2 Drip irrigation components

A typical drip irrigation system has many components including, (i) Head works consisting of control unit, filters and fertilizer applicators, (ii) Water distribution pipes network consisting of main, sub main and laterals, (iii) Water emitting devices, (iv) Flow regulating and flushing devices and (v) Automation unit and sensors. Depending upon the crop need, size of the farm, quality of available water, application of chemicals and fertilizers with irrigation water the need of many a component is decided (Fig. 5.5).

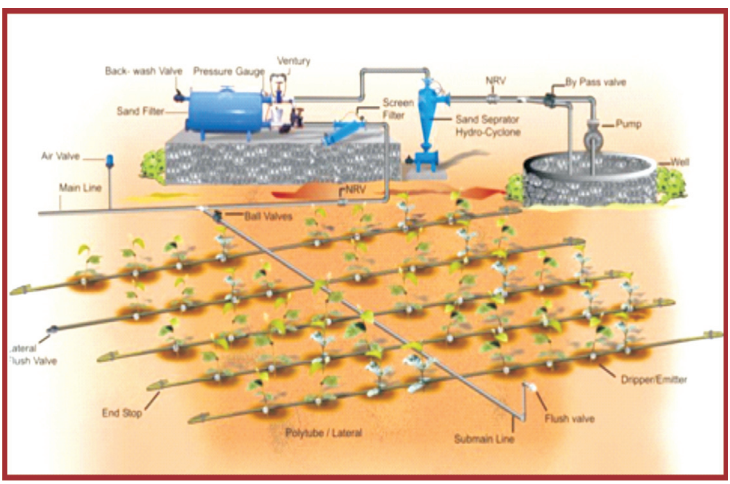

Fig. 5.5: Drip irrigation system

5.1.3 Advantage of drip irrigation

- 40-100 % of water can be saved over flood method. Runoff and deep percolation losses are nil or negligible
- Water use efficiency of drip irrigation is 90-95 %
- Labour is required only to start and stop the system
- Weeds infestation is very less or almost nil due to less wetting of soil
- Saline water can be used. Frequent irrigation keeps the salt concentration within root zone soil below harmful level
- Diseases and pest problems is relatively less because of less atmospheric humidity
- Suitable under various soil physical constraints as flow rate can be controlled.
- Water control is very precise, high and easy.
- Use of fertilizer efficiency is very high due to reduced loss of nutrients through leaching and runoff water.
- Partial and controlled wetting of soil surface eliminates any possibility of soil erosion.
- Frequent watering eliminates moisture stress and yield can be increased up to 20-100%.

5.1.4 Limitations of Drip Irrigation

- Salinity hazard - in long run in absence of leaching of salts built up.
- Sensitivity to clogging of system components.
- High cost of irrigation systems.
- Requirement of high skill in design, installation and operation

5.1.5 Clogging and its Control in Micro Irrigation System

Partial or total clogging of drippers/sprinkler nozzles is a chronic problem and the most serious constraint to the long-term operation of drip irrigation system. Inadequate consideration of the physical, biological and chemical characteristics of the water supply will result in serious clogging problems.

5.1.6 Solution to clogging problems

The clogging can be prevented by adequate filtration. Sand from well water can be removed by centrifugal separators. Suspended organic matter and clay particles can be separated with gravel filters, disk and screen filters, which have to be cleaned periodically. Filtration is not sufficient when wastewater is used for drip irrigation - chlorinating or some other method of disinfecting is needed to prevent growth of bacterial slimes and algae. Some of the precipitates can be dissolved by injecting dilute Hydrochloric acid into the systems. Bacterial slime can be dissolved by hypochloritic injection.

5.1.7 Maintenance of drip irrigation system

Regular maintenance of drip irrigation system is essential for its successful functioning.

1. Check for emitting device functioning, discharge, wetting zone, leakages of pipes, valves, fittings etc,
2. Check placement of drippers
3. Check for leakages through filter gaskets in the lids, flushing valves, fittings etc.,
4. Check the filter for the debris

5.1.8 Fertigation

Fertigation is the process of application of water-soluble solid fertilizer or liquid fertilizers through drip irrigation system (Fig. 5.6). Through fertigation nutrients are applied directly

Fig. 5.6: Banana under drip fertigation

into the wetted volume of soil immediately below the emitter where root activity is concentrated. In fertigation, plants receive small amounts of fertilizer early in the crop's season, when plants are of the vegetative stage. The dosage is increased as fruit load and nutrient demands grow, and then decreased as plants approach the end of the crop's cycle. This gives plants the needed amounts of fertilizer throughout the growth cycle, rather than a few large doses.

5.1.9 Frequency of Fertigation

Fertilizers can be injected into the irrigation system at various frequencies once a day or once every two days or even once a week. The frequency depends on system design, irrigation scheduling, soil type, nutrients requirement of crop and the farmer's preference.

5.1.10 Methods for fertilizer injection

Fertilizers can be injected into drip irrigation system by selecting appropriate equipment. Commonly used fertigation equipments are: 1) Venturi pumps, 2) Fertilizer tank (By-pass system), 3) Fertilizer injection pump (Fig. 5.7).

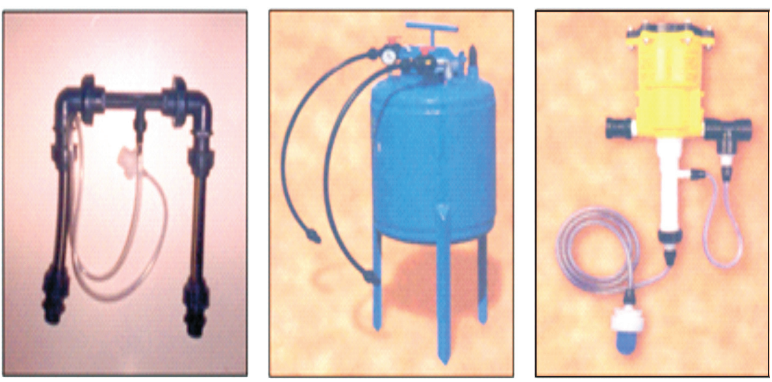

Fig. 5.7: Methods for fertilizer injection

5.1.11 Preparation of NPK stock solution

An example given below to instruct users how to prepare their own solutions.

To prepare 100 litre stock solution type "6.4-2.1-6.4" (N:P:K)

- Fill 70 liters of water in the tank,
- Add 4 kg MKP,
- Add 14 kg Urea,
- Add 8.2 kg KCl,
- Bring volume to 100 liters

Apply 2 liter stock solution per 1m^3 water to reach 130, 40 and 130 ppm of N, P_2O_5 and K_2O, respectively.

Calculation ....

i) 4 kg MKP = 4 kg MKP x 52% P_2O_5= 2.1 kg P_2O_5/100L
= 21,000 ppm P_2O_5
= 4 kg MKP x 34% K_2O = 1.36 kg K_2O/100L
= 13,600 ppm K_2O

ii) 14 kg Urea = 14 kg urea x 46% N = 6.44 kg N/100L
= 64,400 ppm N

iii) 8.2 kg KCl = 8.2 kg KCl x 61% K_2O = 5 kg K_2O/100L
= 50,000 ppm K_2O

When 2 liters of the stock solution is applied to 1m^3 of water; the plants will receive the following concentrations of N, P and K at the dripper:

N = 64,400 ppm x 2L/1000L = 128.8 » 130 ppm N
P = 21,000 ppm x 2L/1000L = 42 » 40 ppm P_2O_5
K = (13,600+50,000) ppm x 2L/1000L = 127.2 » 130 ppm K_2O

5.1.12 Advantages of Fertigation

i) Ensures a uniform and regular flow of water as well as nutrients, resulting in increased growth rates for higher yields and quality.
ii) Offers greater versatility in the timing of the nutrient application to meet specific crop demands.
iii) Improves availability of nutrients and their uptake by the roots.

iv) Safer application method, as it eliminates the danger of burning the plant root system.
v) Simple and more convenient application method that saves time, labor and energy.
vi) Timely applications of small but precise amounts of fertilizer directly to the root zone, this improves fertilizer use efficiency and reduces nutrients leaching below the root zone.
vii) Cost of application by fertigation is about one-third the cost of conventional application methods.

5.1.13 Disadvantages of Fertigation

i) Uneven nutrient distribution when the irrigation system is faulty.
ii) Over fertilization if excess water is applied to the crops.
iii) Chemical reactions of fertilizer with calcium and bicarbonate in water, which can lead to clogging of drip fertigation system.
iv) Potential chemical back flow into water supply.
v) Safe and effective fertigation requires careful and attentive management.
vi) Beneficial only when the micro irrigation system is adequately designed, fully functional and properly managed

5.1.14 Benefits and cost analysis

The cost of micro irrigation system depends to a large extent on the type of crop, its spacing, water requirement, proximity to water source etc. The relative cost of the system decreases with increase in the area since certain essential components remain the same irrespective of the area covered. The increase in yield in drip irrigation ranged as high as 100 percent in bananas, 40 to 50 percent in sugarcane, pomegranate, tomato, and chillies and around 25 percent in grapes, cotton and groundnut. In these crops, the irrigation water savings compared to conventional methods ranged from 40 to 70 percent. The payback period ranged from 1 to 4 years only in different crops as against a life span of 8 years for the drip system.

5.1.15 Micro Irrigation (MI) Scheme

It is a Centrally Sponsored Scheme under which out of the total cost of the MI System, 40 % will be borne by the Central Government, 10 % by the State Government and the remaining 50 % will be borne by the beneficiary either through his/her own resources or soft loan from financial institutions. The estimated cost of drip irrigation system for different crop spacing and plot sizes is given in Table 5.1

Table 5.1 Estimated Cost of Installing Drip Irrigation System

(Cost in Rupees)

Spacing(m)	Area (ha)					
	0.4	1	2	3	4	5
12x12	10600	16700	25200	32600	53700	71300
10x10	12100	18000	27700	36000	57900	76900
9x9	12400	22100	35500	55900	61400	81100
8x8	12900	19900	31300	41700	65500	86200
6x6	14400	30200	51200	70300	105800	137400
5x5	15100	32800	56600	83100	117100	150800
4x4	16900	39300	63100	100700	142200	179300
3x3	17900	35600	71400	96100	130800	158300
3x1.5	19700	40200	80500	109700	146100	180900
2.5x2.5	20000	39800	81400	111200	199500	239600
2x2	21300	49800	86400	122700	164900	223400
1.5x1.5	26100	55000	109500	165100	205900	281000
1x1	26500	57600	96500	146500	199900	249200

Assistance will be available to the farmers growing all horticultural crops like fruit, vegetables including potato, onion and other root and tuber crops, spices, medicinal & aromatic plants, all plantation crops excluding tea, coffee, rubber and oil palm. Only new installations i.e. systems invoiced and installed during 2005-06, which have not availed any subsidy under any of the Government Schemes shall be eligible for assistance under the Scheme.

5.2 Sprinkler Irrigation

In order to increase the crop production in keeping with the population growth, more area of lands is to be brought under irrigation this is possible only by introducing the sprinkler and drip system, replacing surface methods for certain crops and certain location. In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifice and nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressures and sprinkler spacing the amount of irrigation water required to refill the crop root zone can be applied nearly uniformly at a rate to suit the infiltration rate of the soil, thereby obtaining efficient irrigation. Sprinkler irrigation is suitable for closely spaced crops like groundnut, cotton, sugarcane, millets and pulses, forage crops and drip irrigation for wide spaced high value crops like coconut, grapes, banana, limes and vegetable crops. These methods are becoming increasingly popular in India in regions of water scarcity where water is insufficient to irrigate the command area by the surface method.

5.2.1 Types of sprinkler system

Sprinkler systems are of the following two major types on the basis of the arrangement for spraying irrigation water:

5.2.1.1 *Rotating Head or Revolving Sprinkler System*

This can again be divided into three categories namely:

Conventional System/Small Rotary Sprinklers

Small size lateral pipes are placed on riser pipes fixed at uniform interval along the length of lateral pipes. The sprinkler operate low to medium pressures of 2 to 4 bar and can irrigate an area of 9-24 m wide and up to 300 m long at one setting. Application rate vary from 5 to 35 mm per hr.

Boom Type and Self Propelled Sprinkler Systems:

This system employs one boom sprinkler on each lateral. The boom is a nozzled, slowly rotating pipeline, which is suspended from a portable tower. The large sprinkler irrigates a width of 75 to 100 m depending on nozzle sizes and pressure and is particularly useful for tall crops such as corn and sugarcane, where space at regular intervals is available for maneuvering the portable tower.

Mobile Rain Gun/Large Rotary Sprinklers:

This system operates at high pressure to irrigate large areas. The term 'raingun' is used to describe them because of large size of sprinkler used and its ability to throw a large quantity of water over wide areas. They can irrigate areas up to 4 ha at one setting with an application rate varying from 5 to 35 mm per hour.

5.2.1.2 ***Perforated Pipe System***

This method consists of drilled holes or nozzles along their length through which water is sprayed under pressure. The system is usually designed for relatively low operating pressures of about 0.5 to 2.5 kg /cm^2. The sprays are directed on both side of pipe and can cover a strip of land from 6 to 15 m wide. The application rate ranges from 1.25 to 5 cm per hour is for various pressures and spacing. It is therefore limited to use in soils having fairly high intake rates (Sivanappan, 1987).

Based on the portability, sprinkler systems are classified into the following types:

- **Portable System :** A portable system has portable main lines, and laterals and a portable pumping plant. It is designed to be moved from field to field or to the different pump sites in the same field.
- **Semi Portable System :** A semi portable system is similar to a fully portable system except that the location of the water source and pumping plant are fixed. Such a system

may be used on more than one field where there is an extended main line, but may not be used on more than one farms unless there are additional plants.

- **Semi Permanent System:** A semi permanent system has portable lateral lines, permanent main lines and sub mains, and a stationary water source and pumping plant. The main lines and sub mains are usually buried, with riser for nozzle locate at suitable intervals.
- **Solid Set System:** A solid set system has enough laterals to eliminate their movement. The laterals are positioned in the field early in the crop season and remain for the season. The system is used for the crops requiring short and frequent irrigations.
- **Permanent System:** A fully permanent system consists of permanently laid mains, sub mains and laterals and a stationary water source and pumping plant. Mains, sub mains and laterals are usually buried below plough depth. Sprinklers are permanently located on each riser. Such systems are costly and are suited to automation of system with moisture sensing device. Sprinkler installations in orchards are usually of permanent type.

5.2.2 Application rate of the sprinkler system

The rate of application of the sprinkler system is limited by infiltration capacity of the soil. Soil type, crop cover and slope need to be taken into consideration in deciding the application rates. Application rate in excess of the infiltration capacity of the soil will cause surface runoffs, which will results in water loss, poor distribution of water and soil erosion. Table 5.2 gives the maximum application rates for different soil conditions.

5.2.3 Crop Response to Sprinkler

These systems are suitable for irrigating crops where the plant density is very high where adoption of Drip Irrigation Systems

Table 5.2 Suggested maximum application rates for sprinklers for average soil, slope and tilth

Soil texture and profile	0.5 per cent slope, cm/h	5 to 8 per cent slope, cm/h	8 to 12 per cent slope, cm/h
Coarse sandy soil to 2 m	5.10	3.75	2.54
Coarse sandy soils over more compact soils	3.75	2.54	1.90
Light sandy loam to 2 m	2.54	2.03	1.50
Light sandy loams over more compact soil	1.90	1.27	1.02
Silt loams to 2 m	1.27	1.02	0.76
Silt loams over more compact soils	0.76	0.63	0.38
Heavy textured clays or clay loams	0.38	0.25	0.20

may not be economical. Sprinkler irrigation is suitable for horticultural crops like vegetables and seed spices. Conventionally, sprinkler irrigation has been widely in use for irrigating Cereals, Pulses, Oil Seeds and other field crops. The trials conducted in different parts of country revealed water saving due to sprinkler system varies from 16 to 70 % over the traditional method with yield increase from 3 to 57 % in different crops and agro climatic conditions.

5.2.4 Advantages of Sprinkler Irrigation

- Saving of water varies from 25 to 50 % for different crops.
- When water is spread like rain there is little or no puddling effect on soil.
- There will be no soil erosion problem, no compaction of soil during irrigation, no land levelling required, no land being lost to formation of ditches.
- Areas located at a higher elevation than the source can be irrigated.

- Suitable for irrigating crops where the plant population per unit area is very high. It is most suitable for oil seeds and other cereals and vegetable crops.
- Fertilizer can also be applied through the sprinkler system, which saves on labour.
- It may well be less expensive than the surface method, since land levelling is extra and construction of channels is not needed.

5.2.5 Disadvantages of Sprinkler Irrigation

i) High wind distorts sprinkler patterns and cause uneven distribution of water.

ii) Ripening of fruit must be protected from the spray.

iii) A stable water supply is needed for the most economical use of the equipment.

iv) The water must be clean and free of sand debris and large amounts of dissolves salts.

v) The sprinkler method usually requires the highest initial investment.

vi) Power requirement is usually high.

vii) High water pressure required in sprinkler (>2.5 kg / cm^2)

viii) More water is lost by evaporation during sprinkling under high temperature.

ix) Fine texture soils that have a slow infiltration rate cannot be irrigated efficiently in hot windy area.

x) Difficulty in irrigation during wind in sprinkler.

5.2.6 Sprinkler system operations and maintenance

Operational Problems

Operating Pressure of Sprinkler: The operating pressure of sprinkler is important to achieve the desired uniformity of more than 80 % in the field. The setting of optimum pressure through can be achieved by proper selection of pump, providing of Bye Pass arrangement, use of Booster Pumps etc.

Blockage

- Use of the flush valve assembly on the lateral end.
- During installation keeping riser pipe open.
- Stones / vegetative material chocking the spreader and range nozzle.
- Provide wire mesh to foot valve suction area.

Leaking of Couplers, Saddles

- The gaskets are not properly installed, check the welded joint.
- The clamp and latches, saddles nut and bolt are not properly fixed.

Sprinkler is not operating properly:

- Check spring tension, check rubber and Teflon gaskets, check swing arm alignment, check pivot pin etc.

5.2.7 Maintenance of Sprinkler System

- Coupler joints: The jointing in case of quick coupled of HDPE pipe is damage or welded joint is detached.
- Rubber gaskets: Change the rubber gaskets due to wear or loosing of the property.
- Sprinkler parts: The retail shops of dealer for repairing check periodically the sprinklers; use manufacturer's guidelines available for sprinkler maintenance.
- Storage of pipes and fittings: Store the pipes and fittings in dry place. Avoid place where rodents problem is envisaged. Keep rubber gaskets at proper place after removing from pipe.
- Maintenance of pump: Maintenance of pumps to be carried out like pump leaking glands, suction pipes with foot valves, screens for submersible pumps etc.

5.3 Rain gun Sprinkler Irrigation System

Wheat and rice are generally grown in basins and subjected to availability of water for flood irrigation. Rice farmers in particular, tend to believe that it requires standing water during the growing season to maximize yields. These practices consume water far in excess of crops' evapotranspiration requirements and result in very low irrigation efficiencies. On-farm irrigation efficiencies range between 30 to 70%. Large reductions in water use can be obtained, if seepage and percolation losses are minimized. Percolation losses in gravity fed irrigation fields can be minimized by modifying soil physical properties by puddling, shallow soil tillage, soil compaction with heavy machinery or by introducing physical barriers beneath the root zone. Reduction in water use can also be obtained by managing depth of standing water during growing season by alternate wetting and drying or by saturated soil culture. Alternatively, large volume sprinklers such as raingun can be used to grow grain crops particularly rice and wheat with much less water than required with the conventional methods of irrigation.

There have been attempts to adopt pressurized irrigation methods to grow crops in various states on India through getting subsidy under National Mission on Micro Irrigation (Ministry of Agriculture). Sprinkler systems such as portable rain-guns can be used to apply a desired depth of water during pre-sowing and subsequent irrigations. The application of irrigation water with rain gun sprinklers has improved on-farm irrigation efficiencies up to 70-80 % under the prevailing climatic conditions in the India.

Rain gun is a powerful mega sprinkler that throws a large amount of water (up to 500 liters per minute) and radius of throw from 24 m to 36 m and even more as artificial rain. Large volume sprinkler irrigation systems (rain guns) are used where larger areas are to be covered with one or two sprinklers. As these systems cover larger areas they require high pressure and high discharge pipes & pumps to operate them. These are preferred for irrigating crops spread over large areas in short time (Fig. 5.8)

Fig. 5.8: Rain gun in operation

Rain gun irrigation with improved management technologies and in all the cases the system is viable for more than 10 years under good maintenance. The payback period is 2-3 years only indicating the viability of the investment.

A rain-gun can cover up to one-acre area under sprinkling from one position in two to three hours only and can be moved-on to cover entire field. All most crops can be irrigated by Rain-guns. Rain gun works with inlet water having pressure of about 2.5 to 3 kg/cm^2 and rotates automatically to full circle or part circle operation giving a sprinkling diameter of 200 to 400 ft depending on the model chosen (Fig. 5.9).

Fig. 5.9: Rain gun installed in field

Rain-gun Irrigation system can be designed with either a ***fixed system***, where only a rain-gun is required to be moved on underground outlets or a ***portable system*** where a portable lateral with rain-gun stand is progressively moved.

5.3.1 Portable hand move system: PVC pipeline is laid underground through center of the field with quick-fit riser-outlets (End plugged) spaced at every 30 to 40 m. One of these outlets gets connected progressively to Rain - gun mounted on trolley wheel Stand, through portable quick fit laterals of HDPE/ Aluminium sprinkler pipes.

5.3.2 Fixed system: PVC main and sub mains are laid underground at suitable distances with riser-outlets spaced throughout the field. Only rain-gun is required to be shifted progressively on these outlets, covering entire farm in the irrigation cycle. The cost of such installation is around Rs 10,000/- to Rs 15,000/-per acre and is highly convenient for high value and dense crops with considerable saving in labour for shifting pipes.

After working at one position for about 2 hrs (depending on the crop, season and soil) the rain-gun is shifted to next position, such that the whole area is irrigated in a cycle of one to one. The installation cost for portable Rain-gun system is very low approximately Rs. 2,500/- to 3,500/- per acre.

5.3.3 Automatic travelling rain gun system : This Irrigator machine is complete unit in itself, having HDPE pipes rolled on its turbine -driven reel. Driven by inlet water pressure, the turbine mechanism rolls, HDPE pipes, which has been first laid through the farm (Fig. 5.10). Trolly mounted Rain-gun unit which is attached at the end of the pipe line moves slowly towards the machine, giving rain required its length of run.

The traveling speed is adjustable for giving required rain over a period. This machine is very popular overseas, as it saves on labour fully while irrigating. The cost of this machine is from Rs. 1.2 Lacks to Rs. 6 Lacks depending on the model and capacity.

Fig. 5.10: Travelling rain gun

Selection of rain gun sprinkler: Application rate of rain gun nozzle must be less than intake rates of soil (Table 5.3) (Fig. 5.11).

Table 5.3 Soil texture and maximum application rate

Soil Texture	Maximum application rate (mm/h)
Coarse Sand	20 to 40
Fine Sand	12 to 25
Sandy Loam	12
Silt Loam	10
Clay Loam/Clay	5 to 8

Fig. 5.11: Rain gun nozzle

5.3.4 Time required for irrigation : It mainly depends on the effective root zone depth of the crops. For e.g. sugarcane on an average a rain gun can irrigate nearly half acre in 1 to 1.5 hours. Using flood irrigation, farmers nearly take 4 hours to irrigate 0.5 acre of sugar cane. For onion and vegetable 45 minutes is enough to irrigate 0.5 acre.

5.3.5 Power requirement to operate the Rain gun : Minimum power requirement to operate the raingun is 5 hp. Power requirement depends on the nozzle discharge, wetted radius and operating pressures.

Power requirement depends on many factors.

The make of the pump, i.e. some pumps have low pressure but high discharge. This pump generates low pressure. Some Pumps generate high pressure with low discharge.

5.3.6 Suction and delivery heads : Suction head – distance from the pump to the foot valve. Delivery head – distance from the pump to the G.L. If the suction head is more than 40 feet, much of the energy of the pump is wasted in sucking water up to 40 feet. So this will reduce the outflow pressure of the water.

Lesser the suction, higher will be the pressure. Open well submersible pumps have 'O' suction head. So, we may get high KSC pressure in these pumps.

Conveying distance between the pump and the rain gun - larger the distance between the pump and the location of the rain gun, lesser will be the pressure due to frictional loss and conveyance loss.

5.3.7 Types of pipes should be used for Rain Gun : The best choice would be HDPE pipes, which can be assembled and dismantled easily. If the pump is less than 3.0 kg/cm^2, rain gun can be operated using PVC pipes. If the pressure exceeds 3.0 kg/cm^2, HDPE pipes will be the most appropriate choice.

5.3.8 Area covered by a the rain gun : It again depends on the pump / motor. Higher the H.P., higher will be the operating pressure. Higher the pressure, larger will be the throw distance. Larger the throw distance, larger will be area covered. For e.g. if the radius of the throw is say 18 meter,

Area covered = 3.14 x 18 x 18 = 1017 m^2
It is slightly more than ($1/4^{th}$ acre)

5.3.9 Height required of the stand : It depends on the type of crop. For Sugarcane and cotton, 5′ height stand is required. For other crops like wheat, vegetables, tea, coffee, ground nut, etc., 3′ to 4′ height stand is enough.

5.3.10 Advantage of Rain Gun over flood irrigation

i. Reduces water consumption by up to 50% compared to traditional irrigation methods

In flood irrigation, more than 75% of the water goes as percolation loss (say 25% of water is available at Effective root Zone Depth). In any agriculture, the top soil is more fertile (for this only we apply fertilizers and manures). In flood irrigation, the fertility in top soil is washed away and goes as percolation loss i.e. the top soil is leached away. In Rain Gun irrigation as we irrigate only up to the E.R.D, there is no percolation loss or leaching.

ii. Reduces irrigation time and hence power consumed by 40-50%

As $1/4^{th}$ acre could be irrigated within 1 to 3.5 hours, the total extend of area irrigated per day nearly doubles. So, if a farmer cultivates 5 acre sugarcane with his available water and pump in flood irrigation, he can cultivate 10 acres of land by using Rain Gun with the very same availability of water and pump.

iii. Increases crop yield by up to 10% (after continuous usage for 2-3 years) through Nitrogen-fixation

Rain gun irrigation plays the role of nitrogen fixation. One of the major nutrient plants requires is nitrogen. Atmospheric air contains 78% of nitrogen. Water applied through rain gun resembles like rain, the water dissolves the nitrogen from air and gives it to soil, thereby adding nutritive value to soil. This is one of the reasons for increase in yield.

iv. Can be used to irrigate multiple crops

v. Reduces pest and insects attack: Pests and insects get washed away during Rain Gun irrigation

vi. Uniformity in irrigation

In flood irrigation, farmers usually open the delivery at one corner of the field and it goes to the next corner and entire field by gravity. In well-grown sugarcane fields, farmers are unable to go and inspect if the entire field gets uniformity in irrigation. If there is any undulation in the topography of the land, water may not reach to that part, where as in rain gun irrigation, the uniformity of the entire field is ensured.

vii. Easier application of fertilizer and pesticides

In well grown sugarcane, farmers feel very hard to spray in the interior field. In our rain gun, with a help of a fertilizer tank and a venture assembly, fertilizers and pesticides can be sprayed easily without any labour.

5.3.11 Advantages of rain gun over drip irrigation

- **Less Cost** : For one acre of Sugarcane installation of drip cost around Rs.24,000/-, whereas by using Rain Gun System, the cost comes round Rs.14,000/- only. If a farmer owns 10 acres of sugarcane if he is interested in drip, he has to install drip for the whole 10 acres at a cost of Rs.2,40,000/- where as, if he use rain gun, with a single rain gun he can irrigate 10 acres of land by shifting the gun properly. Drip irrigation cannot be shifted.

- **Clogging problem** : In drip, the water oozes out through a small hole less than 1 mm, which gets clogged by the calcium carbonate and other chemicals available in water. So, after a period of one year most of the drippers get clogged. In Rain Gun, there is no clogging problem irrespective of the quality of water.

- **Easy intercultural operation** : An intercultural operation in a drip field is a task, whereas it is easy in rain gun irrigation.
- **Less Maintenance**
- **Low price of rain gun :** Average price of one piece of rain gun is near about Rs. 2000 (Fig. 5.12)

Fig. 5.12 : Different types rain nozzles

5.3.12 Application of rain gun

- Recommended for field crops like sugarcane, pulses, oil seeds, cereals, tea, coffee, cardamom, etc., vegetables like Onion, cabbage, potato, cauliflower, carrot, beat root, tapioca, etc. and ground nut etc.
- Easy to use with portable irrigation system.
- Useful for large turfs, lawns and playgrounds.

5.3.13 Financial assistance for adoption of rain gun sprinkler system

A Centrally Sponsored Scheme on Micro Irrigation was introduced in January, 2006 to increase the area under improved methods of irrigation for better water use efficiency to provide stimulus to agricultural growth. Nearly two million hectares have so far been brought under micro irrigation through this scheme, which is extremely miniscule when compared to the potential of 69 million ha. Government of India has, therefore, decided to impart further thrust to this scheme by implementing it in a mission mode as the National Mission on Micro Irrigation (NMMI). The Mission will help converge micro irrigation activities under major government programs such as Horticulture Mission for North East & Himalayan States (HMNEHS), National Horticulture Mission (NHM), Rashtriya Krishi Vikas Yojana (RKVY), National Food Security Mission (NFSM) etc. to create integrated water harvesting structures for increasing water use efficiency, crop productivity and farmers' income. It is expected that adoption of improved methods of irrigation such as drip & sprinkler would not only save water, power, fertilizer consumption, weeding cost, etc. but would also mitigate environmental degradation such as water logging and soil salinity.

Expenditure on the implementation of NMMI Scheme will be shared in the ratio of 50:10:40 between Central Government, State Government and the beneficiary in case of Small and Marginal farmers. In other words, subsidy assistance for Small and Marginal farmers will be @ 60% of the cost of the drip / sprinkler irrigation system and the remaining 40% will have to be borne by the farmer. In case of general category farmers, subsidy assistance will be @ 50% of the cost of the system which will be shared in the ratio of 40:10:50 by the Central Government, State Government and the beneficiary.

The term "Beneficiary" under the scheme is defined as "every land holder, who possesses own land or leased land for a period of at least the projected life of the irrigation system (10 years) for the purpose of growing crops and who has a water source, either own or shared." The benefit of the scheme will also be available to public sector undertakings/ ICAR / SAUs and on land belonging to Government. All farmers are entitled to avail assistance for various components of the Mission limited to a total area of 5 hectares per beneficiary.

The cost of sprinkler irrigation for one hectare plot with different coupler diameters is given in (Table 5.4), the indicative cost of large volume sprinklers (rainguns) in (Table 5.5) and the rain gun system design for 1 and 4 ha area in (Table 5.6).

Table 5.4 Cost of Sprinkler Irrigation System

Coupler diameter (mm)	Cost (Rs.)
63 mm	13690
75 mm	14270
90 mm	17280

Table 5.5 : Indicative Cost of Large Volume Sprinklers (Rainguns)

Area	Diameter of main/sub main pipe, mm		
	63 mm	75 mm	90 mm
More than 0.4 ha to 1.0 ha	24940	30011	NA
More than 1.0 ha to 2.0 ha	NA	38075	NA
More than 2.0 ha to 3.0 ha	NA	NA	54112
More than 3.0 ha to 4.0 ha	NA	NA	62720
More than 4.0 ha to 5.0 ha	NA	NA	68878

Financial assistance to the beneficiary for sprinkler irrigation will be limited to 50 percent of the system cost subject to a maximum of Rs.7500/- per ha. Since sprinkler systems are moveable, the cost of the system will be governed by the actual quantity of material used. Only those farmers who have not availed of assistance for sprinkler irrigation from any other scheme would be eligible for assistance under this scheme. Assistance for

Table 5.6 : Rain gun system design for 1 and 4 ha area

Area to cover under irrigation	**4 hectare 300m x 135m**	**1 hectare 100m x 100m**
Irrigation water applied per irrigation	38 mm	50 mm
Frequency of Irrigation	8 days	10 days
No of Rain Guns used	1 nozzle	1 nozzle
Discharge Capacity of Rain Guns	15000 Lph	11040 Lph
Nozzle application rate	10.8 mm/h	10.1 mm/h
Working pressure of rain-gun	2.5 kg/m^2	2.0 kg/m^2
Spacing between two Rain gun setting on main & laterals	36m x 36m	32m x 32m
Area covered per setting for rain gun irrigation	1296 m^2 (=1300 m^2)	1024 m^2
Time required per setting	3.5 h	5.0 h
Number of rain gun setting per day	4 No	1 No
Area covered per day	5,200 m^2	1024 m^2
Area covered per cycle	41600 m^2 (4 ha)	10240 m^2 (1 ha)
Maximum friction loss in main + Lateral	12 to 15 m	3 to 5 m
Total head required (excluding depth of water source	40 m	30 m
Length and Diameter of mains	300m x 75mm	100m x 75mm
Length & Diameter of high pressure lateral hose	60 m x 75 mm	-

sprinkler irrigation will be limited to only those crops for which drip irrigation is uneconomical. A farmer shall be eligible for assistance only if adequate water is available for the area proposed to be brought under Sprinkler irrigation.