UNIT-1

1.1 Present and Future need of Micro Irrigation

About 42 million ha area is potential under drip and sprinkler in the country (Raman 2010). Out of this, about 30 million ha are suitable for sprinkler irrigation for crops like cereals, pulses and oilseeds in addition to fodder crops. This is followed by drip with a potential of around 12 million ha under cotton, sugar cane, fruits and vegetables, spices and condiments; and some pulse crops like red gram, etc.The percentage of actual area against the potential estimated under drip irrigation in different states varied between nil in Nagaland to as much as 49.74% in Andhra Pradesh, followed by Maharashtra (43.22%) and Tamil Nadu with 24.14%. In case of sprinkler irrigation, the percentage of actual area against the potential estimated was as much low as 0.01% (Bihar) and the highest of 51.93% (Andhra Pradesh). Compared to the potential of 42.23 million ha in the country, the present area under MI accounts for 3.87 million ha (1.42 million ha under drip and 2.44 million ha under sprinkler) which is about 9.16% (Table 1). The present figures thus reflect the extent of MI systems covered under different government programmes as well as own investment by the farmers. However, the actual area under MI may vary according to the extent of use by the farmers. (Palanisami et al., 2011)

Table 1. Potential and actual area under MI in different states (Area in '000 ha)

State	Drip			Sprinkler			Total		
	P	A	%	P	A	%	P	A	%
Andhra Pradesh	730	363.07	49.74	387	200.95	51.93	1,117	564.02	50.49
Bihar	142	0.16	0.11	1,708	0.21	0.01	1,850	0.37	0.02
Chattisgarh	22	3.65	16.58	189	59.27	31.36	211	62.92	29.82
Goa	10	0.76	7.62	1	0.33	33.20	11	1.09	9.95
Gujarat	1,599	169.69	10.61	1,679	136.28	8.12	3,278	305.97	9.33
Haryana	398	7.14	1.79	1992	518.37	26.02	2,390	525.50	21.99
Himachal Pradesh	14	0.12	0.83	101	0.58	0.58	115	0.70	0.61
Jharkand	43	0.13	0.31	114	0.37	0.32	157	0.50	0.32
Karnataka	745	177.33	23.80	697	228.62	32.80	1,442	405.95	28.15
Kerala	179	14.12	7.89	35	252	7.19	214	16.64	7.77
Madhya Pradesh	1,376	20.43	1.48	5,015	117.69	235	6,391	138.12	2.16
Maharashtra	1,116	482.34	43.22	1,598	214.67	12.53	2,714	697.02	25.68

Nagaland	11	0.00	0.00	42	3.96	9.43	53	3.96	7.48
Orissa	157	3.63	2.31	62	23.47	37.85	219	27.10	12.37
Punjab	559	11.73	2.10	2,819	10.51	0.37	3,378	22.24	0.66
Rajasthan	727	17.00	2.34	4,931	706.81	14.33	5,658	723.82	12.79
Tamil Nadu	544	131.34	24.14	158	27.19	17.21	702	158.52	22.58
Uttar Pradesh	2,207	10.68	0.48	8,582	10.59	0.12	10,789	21.26	0.20
West Bengal	952	0.15	0.02	280	150.03	53.58	1,232	150.18	12.19
Others	128	15.00	11.72	188	30.000	15.96	316	45.00	14.24
Total	11,659	1,428.46	12.25	30,578	2442.41	7.99	42,237	3,870.86	9.16

P= Potential; A=actual area

Source: Raman (2010) and India stat 2010.

1.2 Role of Govt. for the promotion of Micro- Irrigation

India is an agrarian country. Water management is of critical importance to Indian agriculture. While the irrigated area in the country has almost doubled since independence, it is believed that the irrigated area cannot exceed 50% of the cultivable area with the conventional methods of irrigation even if the irrigation potential is fully utilized. To address the judicious and improved methods / technologies for harnessing maximum benefits from available water resources to enhance crop productivity without affecting soil health. The scheme on Micro- Irrigation, which was launched during the year 2005-06, has been upscaled to be implemented as the 'National Mission on Micro-irrigation' (NMMI) during XI Plan period.

The main objectives of NMMI are:

- To increase the area under micro-irrigation through improved technologies.
- To enhance the water use efficiency.
- To increase the productivity of the crops and farmers' income.
- To establish convergence and synergy among ongoing Govt. programmes.
- To promote, develop and disseminate MI technology for agriculture or horticulture development with modern scientific knowledge.
- To create employment opportunities for skilled and unskilled person especially unemployed youth

This 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. Assistance for beneficiary farmers will be for covering a maximum area of 5ha/ beneficiary.

At least 33% of the allocation is to be utilized for small, marginal and women farmers. The allocation to SC/ST farmers will be proportionate to their population in the district. Farmers who have already availed the benefit of subsidy can again avail subsidy after 10 years.

The assistance for MI demonstrations, to be taken in farms belonging to State/Central Governments, State Agricultural Universities (SAUs) and ICAR Institutions, progressive farmers and Non-Governmental Organizations (NGO)/Trusts, on their own land will be @ 75% of the cost for a maximum area of 0.5 ha per beneficiary, which will be met entirely by the Central Government.

Assistance will be available for both drip and sprinkler irrigation for wide spaced as well as close spaced crops. However, assistance for sprinkler irrigation system will be available only for those crops where drip irrigation is uneconomical. Assistance is also available for irrigation systems for protected cultivation including greenhouses, polyhouses and shadenet houses. Assistance is available for implementation of advanced technology like fertigation with fertilizer tank / venture systems, sand filters / media filters, hydrocyclone filters / sand separators and other different type of filters and valves required for MI system.

The Panchayati Raj Institutions (PRIs) are involved in selecting the beneficiaries. The scheme includes both drip and sprinkler irrigation. However, sprinkler irrigation will be applicable only for those crops where drip irrigation is uneconomical. There will be a strong HRD input for the farmers, field functionaries and other stake holders at different levels. Besides, this there is provision for be publicity campaigns, seminars/workshops at extensive locations to develop skills and improve awareness among farmers about importance of water conservation and management. The Precision Farming Development Centres (PFDCs) provide research and technical support for implementing the scheme. Supply of good quality system both for drip and sprinkler irrigation having BIS marking, proper after sales services to the satisfaction of the farmer is paramount.

At the National Level, the Executive Committee of NMMI reviews the progress of NMMI and approve the Annual Action Plans of States. At the State level, the State Micro-irrigation Committee (SMIC) woversees the implementation of the Mission programme in districts. The District Micro-irrigation Committee (DMIC) coordinates the implementation of NMMI programme at the District level. NCPAH coordinates and monitor the programme of NMMI in different States.

The scheme is implemented by an Implementing Agency (IA) appointed by the State Government, which will be the District Rural Development Agencies (DRDA) or any identified Agency, to whom funds will be released directly on the basis of approved district plans for each year.

The IA shall prepare the Annual Action Plan for the State on the basis of the district plans and get it forwarded by SMIC for approval of the Executive Committee (EC) of NMMI. Payment is made through RTGS to the IA who transfers funds to the identified districts. DMIC provides funds to the system suppliers through the farmers' / beneficiaries'. Registration of System Manufacturers will be done by the SMIC for use in the Districts. Micro-irrigation systems costs have been standardized upon which the subsidy amount is being calculated, as stated in Tables 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6.

Table 1.1 Indicative cost of installing drip irrigation system for calculation of subsidy

Cost in Rs./ha							
Lateral Spacing (m x m)	0.2	0.4	1	2	3	4	5
12 x 12	8057	13785	18820	29928	46467	57809	73611
100 x 10	8308	14277	20041	32323	50128	62787	79831
9 x 9	8490	14631	20900	34039	52704	66294	84219
8 x 8	8673	15088	22028	36217	56087	70893	89964
6 x 6	9492	16605	26551	44387	71715	86970	109129
5 x 5	10061	17977	30143	51438	74334	94465	126925
4 x 4	11177	18621	31793	55725	86926	113812	135459
3 x 3	12088	20048	36551	63269	97448	122553	153441
2.5 x 2.5	14939	27092	52230	95083	145227	203823	248954
2 x 2	18319	31616	63598	123441	179332	249134	305797

B. Close spaced Crops							
1.5 x 1.5	21514	35973	74437	141858	211855	292595	360002
2.5 x 0.6	15463	26791	54909	100906	154213	214153	262885
1.8 x 0.6	18807	32909	70086	132653	199684	271986	338705
1.2 x 0.6	24063	43816	97598	185565	2800886	378946	474070

Table 1.2 Indicative cost of micro sprinkler and mini sprinkler irrigation system

Cost in Rs		
Area (ha)	Micro Sprinkler	Mini Sprinkler
	Spacing of Sprinkler (m x m)	
	5 x 5	10 x 10
0.2	17019	Not Feasible
0.4	51245	35968
1	90070	74097
2	129830	139142
3	175315	211289
4	221628	271958
5	221628	333150

Table 1.3 Indicative cost of drip irrigation/fogging/misting system under protected cultivation

Cost in Rs. per unit)			
SN	**Particulars**	**504 Sqm**	**100 Sqm**
1.	Green House / Poly House a) High Cost b) Naturally Ventialted	55,000	21,000
2.	Shadenet	45,000	18,000

Table 1.4 Indicative cost of portable sprinkler irrigation system

Area	63 mm	75 mm	90 mm
Up to 0.4 ha	10399	NA	NA
More Than 0.4 ha – 1 ha	16993	19044	NA
More Than1 ha – 2 ha	24533	27280	NA
More Than 2 ha – 3 ha	NA	NA	36822
More Than 3 ha – 4 ha	NA	NA	46438
More Than 4 ha – 5 ha	Na	NA	52573

Table 1.5 Indicative cost of semi-permanent sprinkler irrigation system

Area	Cost (in Rs.)
Up to 0.4 ha	19615
0.4 ha – 1 ha	31832
1 ha – 2 ha	60699
2 ha – 3 ha	81929
3 ha – 4 ha	104689
4 ha – 5 ha	127003

Table 1.6 Indicative cost of large volume sprinklers (rain guns)

Cost in Rs.			
Area	**63 mm**	**75 mm**	**90 mm**
More Than 0.4 ha – 1 ha	24940	30011	NA
More Than 1.0 ha – 2 ha	NA	38075	NA
More Than 2.0 ha – 3 ha	NA	NA	54112
More Than 3.0 ha – 4 ha	NA	NA	62720
More Than 4.0 ha – 5 ha	NA	NA	68878

(Source: Guidelines, NMMI)

The total cost of the scheme is being shared between Central Government, the State Government and the beneficiary either through his/her own resources or soft loan from financial institutions in the ratio of 40%, 10% and 50% respectively. Bankable schemes are being formulated for availing bank loans.

1.2.1 Financial support from National Bank for Agriculture and Rural Development (NABARD)

Broad guidelines for scheme formulation by banks for financing drip irrigation systems are available at NABARD. The loans are available to farmers from different banks, through NABARD. Some cooperative societies and IFFCO also provide finances required for the initial installation of the micro-irrigation system.

1.2.2 Financial Assistance from National Horticulture Board (NHB)

National Horticulture Board (NHB) also has a scheme to assist farmers in increasing the produce of horticultural crops. It also includes financial assistance for micro-irrigation. The pattern of assistance of NHB is credit linked back-ended subsidy @ 20% of the total project cost limited to Rs 25 lakh per project in general area and Rs 30.00 lakh in NE Region, Hilly and scheduled areas.

The terms and conditions of the assistance of NHB are as follows:

i) The assistance shall be available for projects covering area above four hectares (above 10 acres) in case of open field cultivation in general area and 5 acres in NE, hilly/scheduled area.

ii) Credit component as means of finance of the project should be term loan from banking or non-banking financial institutions and should be at least 35% (i.e. 15% more than the admissible rate of subsidy.)

iii) Projects shall be appraised to ensure and enable entrepreneur to incorporate essential hi-tech components in the form of planting material, plantation, irrigation, fertilization, vermin-compost unit, precision farming, on farm PHM related infrastructure, GAP etc.; and to that extent, the project shall be integrated in nature.

iv) Normative cost of various components shall be prescribed by NHB.

v) NHB provides financial assistance for creating irrigation infrastructure for digging bore well to a maximum ceiling of Rs. 4.00 lakh per unit maximum upto two units.

vi) Expenses towards sprinkler system upto 10 Acres with maximum ceiling of 1.0 lakh for installation drip system upto 2.0 lakh.

1.3 Merits and demerits of micro-irrigation

Merits of micro-irrigation over other irrigation systems

Micro-irrigation systems have many potential advantages when compared to other irrigation methods.

1. **Water savings**: Irrigation water requirements can be much smaller when compared with other irrigation methods. This is due to irrigation of a smaller portion of the soil volume, decreased evaporation from the soil surface and the reduction or elimination of the runoff. Since the micro-irrigation system allows for a high level of water control application, water can be applied only when needed and deep percolation can be minimized or avoided.
2. **Water efficiency**: Micro-irrigation can reduce water usage by 25-40% compared to overhead systems, and 45-60% compared to surface irrigation, because do not wet the entire field, less - evaporation, deep percolation and the runoff minimized, too.
3. **Low application rates**: A low application rate means a less expensive irrigation system and more efficient utilization of pumps, filters and pipelines because these system components may be sized for lower flow rates and used for longer periods of time. Micro-irrigation systems are designed to supply an individual plant's water requirement by a daily application.
4. **Uniformity of water application**: Micro-irrigation systems have an excellent uniformity of water application; therefore all plants receive the same amount of water. Good uniformity results in more efficient irrigation, which leads to savings of water, power and fertilizer. An even, consistent application of water also results in better, more uniform yields, because each plant is given exactly as much water and nutrients as it needs for optimum growth.
5. **Energy saving**: A smaller power unit is required compared to other irrigation systems. Usually, the delivery pipe systems operate under low pressure (2 - 4 bar) and hence it requires less energy for pumping.
6. **Improved chemical application**: Micro-irrigation systems allow for a high level of control of chemical applications. The plants can be supplied with the exact amount of fertilizer required at a given time. Since they are applied directly to the root zone, a reduction in the total amount

of fertilizer used is possible (average 25-50% cost savings in chemicals and fertilizers). This application method is more economical, provides better distribution of nutrients throughout the season and decreases ground water pollution due to the high concentration of chemicals that could ordinarily move with deep percolated water. Other chemicals such as herbicides, insecticides, fungicides, growth regulators and carbon dioxide can be efficiently applied through micro-irrigation systems to improve crop production.

7. **Weed and disease reduction**: Due to limited wetted area, weed growth is inhibited and disease occurrences reduced.
8. **Field operations are more flexible**: Micro-irrigation can be applied on windy days and during operations, can function without interruption when harvesting.
9. **Improved tolerance to salinity**: Micro-irrigation reduces the sensitivity of most crops to saline water, soil-water conditions due to the maintenance of high moisture levels in the root zone. The frequent application of water continually replaces moisture removed by the plant and moves salts away from the plant out to the edges of the root zone. These salts precipitate out of the water at the edge of the wetted parameter. This process prevents the harmful combination of high soil salinity and low moisture from occurring. Therefore, crops under micro-irrigation systems are more tolerant of saline water and soil conditions.
10. **Improved quality and yield**: Crop quality and yield under micro-irrigation is improved because of the slow, regular, uniform application of water and nutrients. In addition damage and losses due to water contact with fruit or foliage are eliminated.
11. **Adoption to any topography and soils**: Micro-irrigation systems can operate efficiently on any topography, if appropriately designed and managed. The low application rate with micro-irrigation systems is ideal for heavy clay soils with low infiltration rates as the water can be applied slowly enough for the soil to absorb it without surface runoff occurring. On the other hand, very sandy soils frequently cannot store large amounts of water. Micro-irrigation is ideal for these soils too, because of its ability to frequently provide small amounts of water to the crop.
12. **Automation**: A micro-irrigation system can be easily automated using electrical solenoid valves and a controller. This allows the system to be operated any time of the day or night and for any desired length of time enabling irrigation managers to take advantage of available crop water use information in determining optimum irrigation time.

13. **Reduced labour cost**: One of the major advantages of the micro-irrigation system is labour savings. Labour requirements are low because of the low application rates allow larger areas to be irrigated at one time and because the systems can be fully automated. In addition to the direct savings in labour, there are often indirect labour savings due to the reduced number of cultivations, the elimination of fertilizer application as a separate operation.

Most of the sprinklers, sprayers and jets are insect protected nozzles are closed after operation to avoid any clogging caused by insects or other debris. If these benefits are not achieved, the investment in a micro-irrigation system is not worth it. Product life with good quality equipment, good operation and management can last upto 15-20 years.

1.4 Demerits of micro-irrigation systems

1. **High initial cost**: The initial investment and maintenance cost for a micro-irrigation system maybe higher than for some other irrigation methods, but the growers should weight the cost against benefits. Filters, pumps, regulators, valves, gauges, chemical injectors and possible automation components add to the cost of a micro-irrigation system. The emitter itself (drip tube/tape, sprayer, and sprinkler) represents only approximately 35 - 37% of the initial system cost. Actual cost will vary considerably depending on the selection of a particular micro system. The growers must understand that a well designed, installed and managed system has water saving and important agronomic, environment and economic benefits.
2. **Pressurized irrigation water**: The irrigation water must be pressurized, resulting in energy costs. The required pressures are generally less than those needed for sprinkler systems, but they are higher than those of flood irrigation systems.
3. **Requires some management and maintenance**: Farming with micro-irrigation systems typically requires a change in cultivation, planting and harvesting practices. Educating growers of these changes is required before and during the first season of the micro-irrigation. These new practices can quickly become a standard part of the farming operation. Micro-irrigation systems normally have greater maintenance because of the small orifice characteristics which are susceptible to clogging from particulate matters, organic matter, and chemical precipitates. Therefore additional maintenance including filtration, injecting chlorine

or acid and flushing lateral lines may be necessary to ensure best performance. Machinery, animals, insects or food traffic in the field can cause leaks in the drip tape. Also in order to realize the many benefits discussed, the grower must constantly be monitoring the growing environment and scheduling irrigation to meet the plant's needs.

4. **Clogging:** One of the biggest problems encountered in micro-irrigation is clogging of emitters. The small openings can be easily clogged by soil particles, organic matter, bacterial slime, algae or chemical precipitates. The micro-irrigation system requires very good filtration (most often recommended 200 mesh filtration degree) even with a good quality water supply. The filtration system should be chosen based on physical, chemical or biological characteristics of the water.
5. **Salt accumulation near the root zone**: Unlike surface and sprinkler irrigation systems, which can flush salts below the crop root zone, micro-irrigation systems tend to move salts to the outer edge of the wetted volume of soil and soil surface. Insufficient rainfall can move the salts back into the root zone and cause damage. Careful management is necessary to ensure that the salts do not migrate back into the active root zone. If the need to leach salts from the root zone becomes critical a sprinkler or surface irrigation system may have to be used to accomplish this purpose effectively. In areas, with heavy rainfall the salts will be washed out of the root zone before significant accumulation occurs.
6. **Seed germination**: Some crops do not germinate well with micro-irrigation systems (usually under drip tube/tape). In these cases portable sprinklers are often used for germination. Once started the crop can be irrigated with micro-irrigation to optimize plant growth.
7. **Moisture distribution/restricted root zone**: Moisture distribution depends largely on the soil type being irrigated by the micro-irrigation system. In some soils, i.e. deep sands, very little lateral water movement (low capillary forces) can create many problems. Under these conditions it is difficult to wet a significant portion of the root zone. It is also more difficult to manage the irrigation without deep percolation since only a small amount of water can be stored in the wetted volume desired. Increasing the number of emitters per plant may improve water distribution in the soil. Therefore, coarse sands will require much closer spacing of emitters than fine soils. In general, for any soil the amount of emitters and their spacing must be based on the geometry of wetted soil volume. Particularly in regions of low rainfall, plant root activity is often limited to the soil zone wetted by the emitters. The irrigator must

remember that the micro-irrigation system is meant to apply small, frequent irrigations. Cover crops cannot be grown year-around due to the localized nature of the water applications.

1.5 Types of Micro Irrigation Systems

The micro irrigation system can be classified in respect to variety of parameters. The micro irrigation encompasses several ways of water application to plants: drip, spray, subsurface and bubbler irrigation.

1.5.1 Drip Irrigation

Drip or trickle irrigation is the newest of all commercial methods of water application. It is described as the frequent, slow application of water to soils through mechanical devices called emitters or applicators located at selected points along the delivery lines. The emitters dissipate the pressure from the distribution system by means of orifices, vortexes and tortuous or long flow paths, thus allowing a limited volume of water to discharge. Most emitters are placed on the ground, but they can also be buried (Fig 1). The emitted water moves within the soil system largely by unsaturated flow. The wetted soil area for widely spaced emitters will be normally elliptical in shape. Since the area wetted by each emitter is a function of the soil hydraulic properties, one or more emission points per plant may be necessary (Howell et al., 1980)

1.5.2 Spray Irrigation

Spray irrigation is a form of irrigation in which pressurized water is sprayed over plants to provide them with water. This type of irrigation is also sometimes called sprinkler irrigation, and it is very widely used all over the world. The spray irrigation sizes can be designed for all size of farms, ranging from a home sprinkler to keep a lawn green to industrial sized sprinklers used to irrigate crops.

Fig 1. Water Irrigation through Drip System

The application of water by a small spray or mist to the soil surface, water travel through the air becomes instrumental in the distribution of water. In this category two types of equipment are in use viz., micro-sprayers and micro-sprinklers. Micro-sprayers and static micro jets are non-rotating type with flow rates ranging from 20 to 150 l/h, whereas, micro-sprinklers are rotating type with flow rates ranging from 100 to 300 l/h. Fig 2 shows operation of micro sprinkler for irrigating a flower bed.

Fig 2. Water Irrigation through Sprinkle System

This system is similar to the way one may water lawn at home - stand there with a hose and spray the water out in all directions. The systems can simply be long hoses with sprinklers along the length or a center-pivot system that traverses a circle in the fields. With a spray irrigation system, the irrigation sprinklers may be fixed in place, or located on movable frames. Some sprinkler heads will only spray in one direction, requiring careful placement, while others will rotate as they spray, and delivering water across a broader area. Rotating heads are often preferred because it allows for the installation of a single sprinkler array to cover a big area.

The center-pivot systems have a number of metal frames (on rolling wheels) that hold the water tube out into the fields. Electric motors move each frame in a big circle around the field (the tube is fixed at the water source at the center of the circle), squirting water. The depth of water applied is determined by the rate of travel of the system. Single units are ordinarily about 1,250 to 1,300 feet long and irrigate about a 130-acre circular area. In high-pressure systems, there can be very big water guns along the tube.

A more "modern" alternative to the high-pressure water guns is the low-pressure sprinkler system. Here, water is gently sprayed downward onto plants instead of being shot high in the air. Low-pressure systems are more efficient in that much less water evaporates or is blown off the fields, if there is a strong wind present.

Sources of water for spray irrigation vary. The utilization of treated wastewater should be encouraged. This is an environmentally friendly choice which reduces the demand for fresh water, nourishes the plants, and reduces wastewater runoff into waterways. Treated wastewater can be used on ornamental crops and landscaping, but it may be banned for use on crops. The source of water can be from wells, reservoirs, rivers, lakes, and streams.

1.5.3 Sub-Surface System

It is a system in which water is applied slowly below the land surface through emitters. Such systems are generally preferred in semi permanent/permanent installations.

Subsurface drip irrigation (SDI) is a low-pressure, high efficiency irrigation system that uses buried drip tubes or drip tape to meet crop water needs. SDI technologies have been a part of irrigated agriculture since the 1960s; with the technology advancing rapidly in the last two decades. A SDI system is a flexible and can provide frequent light irrigations. This is especially suitable for arid, semi-arid, hot, and windy areas with limited water supply. Farm operations also become free of impediments that normally exist above ground with any other pressurized irrigation system. Since the water is applied below the soil surface, the effect of surface infiltration characteristics, such as crusting, saturated condition of pounding water, and potential surface runoff (including soil erosion) are eliminated during irrigation. With an appropriately sized and well-maintained SDI system, water application is highly uniform and efficient. Wetting occurs around the tube and water moves out in all directions. Fig 4.3 shows moisture distribution through a sub surface drip system. Subsurface irrigation saves water and improves yields by eliminating surface water evaporation and reducing the incidence of disease and weeds. Water is applied directly to the root zone of the crop and not to the soil surface where most weed seeds winter over. As a result, germination of annual weed seed is greatly reduced, and lowers weed pressure on beneficial crops. In addition, some crops may benefit from the additional heat provided by dry surface conditions, producing more crop biomass, provided water is sufficient in the root zone. When managed properly, water and fertilizer application efficiencies are enhanced, and labor needs are reduced. Field operations are also possible, even when irrigation is applied.

Fig 3. Surface Drip System

1.5.4 Bubbler System

In this system the water is applied to the soil surface in a small stream or fountain. The discharge rate for point source bubbler emitters is greater than the drip or subsurface emitters but generally less than 225 l/h. Since the emitter discharge rate generally exceeds the infiltration rate of the soil, a small basin is usually required to contain or control the water. Bubbler systems do not require elaborate filtration systems. These are suitable in situations where large amount of water need to be applied in a short period of time and suitable for irrigating trees with wide root zones and high water requirements.

Fig 4. Bubbler System

Unit 2

1.1 Introduction

Water is one of the most critical inputs for agriculture which consumes more than 80% of the water resources of the country. Availability of adequate quantity and quality of water is, therefore, key factors for achieving higher productivity levels. Investments in conservation of water, improved techniques to ensure its timely supply, and improve its efficient use are some of the imperatives which the country needs to enhance. Poor irrigation efficiency of conventional irrigation system has not only reduced the anticipated outcome of investments made towards water resource development, but has also resulted in environmental problems like water logging and soil salinity thereby affecting crop yields. This, therefore, calls for massive investments in adoption of improved methods of irrigation such as drip and sprinkler, including fertigation.

Various options are available for reducing water demand in agriculture. First, the supply-side management practices include watershed development and water resource development through major, medium and minor irrigation projects. The second is through the demand management practices which include improved water management technologies/practices. The micro-irrigation (MI) technologies such as drip and sprinkler are the key interventions in water saving and improving crop productivity. Evidence shows that upto 40% to 80% of water can be saved and water use efficiency (WUE) can be enhanced up to 100% in a properly designed and managed MI system compared to 30-40% under conventional practice (INCID 1994; Sivanappan 1994 cited in Kumar 2012).

The term "micro-irrigation" describes a family of irrigation systems that apply water through small devices. These devices deliver water onto the soil surface very near the plant or below the soil surface directly into the plant root zone. Micro-irrigation is a method for delivering slow, frequent applications of water to the soil using a low-pressure distributing system and special flow-control outlets. Micro-irrigation is also referred to as drip, subsurface, bubbler or trickle irrigation and all have similar design and management criteria. The systems deliver water to individual plants or rows of plants. The outlets are placed at short intervals along small tubing and only the soil near the plant is watered. The outlets include emitters, orifices, bubblers and sprays or micro sprinklers with discharge ranging from 2 to over 200lh^{-1}.

Drip irrigation was developed originally as a sub-irrigation system and this basic idea underlying drip irrigation can be traced back to experiments in Germany in 1860's. The first work in drip irrigation in the U.S.A was a study carried out by House in Colorado in 1913. An important breakthrough was made in Germany way back in 1920 when perforated pipe drip irrigation was introduced.

During the early 1940's Symcha Blass, an engineer from Israel, observed that a big tree near a leaking tap exhibited more vigorous growth than other trees in the area. This led him to the concept of an irrigation system that would apply water in small quantity literally drop by drop. The earliest drip irrigation system consisted of plastic capillary tubes of small diameter (1 mm) attached to 1arge pipes. One of the refinements made by Blass in his original system was coiled emitter. In his early 1960's, experiments in the Israel reported spectacular results when they applied the Blass system in the desert area of the Negev and Arava. Drip irrigation unit in their current diverse forms were installed widely in U.S.A, Australia, Israel, Mexico and to a lesser extent in Canada, Cyprus, France, Iran, New Zealand, UK, Greece and India. With the increased availability of plastic pipes and development of emitters in Israel, it has since become an important method of irrigation in Australia, Europe, Israel, Japan, Mexico, South Africa and the United States (INCID, 1994).

In India drip irrigation was practiced through indigenous methods such as perforated earthenware pipes, perforated bamboo pipes and pitcher/ porous cups. In Meghalaya some of the tribal farmers are using bamboo drip irrigation system for betel, pepper and arecanut crops by diverting hill streams in hill slopes. Earthenware pitchers and porous cups have been used for growing vegetable crops in Rajasthan and Haryana. In India drip irrigation was introduced in the early 70's at agricultural universities and other research institutions. The growth of drip irrigation has really gained momentum in the last one decade. These developments have taken place mainly in areas of acute water scarcity and in commercial/horticultural crops, such as coconut, grapes, banana, fruit trees, sugarcane and plantation crops in the states of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Gujarat.

Micro-irrigation has been accepted mostly in the arid regions for watering high value crops such as fruits and orchard trees, grapes and other vine crops, sugarcane, pineapples, strawberries, flowers and vegetables. Growers, producers and landscapers have adapted micro-irrigation systems to suit their needs for precision water application. Micro-irrigation systems are immensely popular not only in arid regions and urban settings but also in sub-humid and humid zones where water supplies are limited or water is expensive. In urban landscapes, micro-irrigation is widely used with ornamental plantings.

To bring more area under irrigation, it has become necessary to introduce new irrigation techniques viz. Micro & Sprinkler Irrigation for economizing the use of water and increase productivity per unit of water. This technology also arrests water logging and secondary salinization problems of the canal command areas and check the receding water table and deteriorating water quality in the well command areas. Micro-irrigation is to be viewed as a total plant support system starting with planting material to post harvest management and marketing. Therefore, micro-irrigation need be promoted in a holistic manner involving appropriate cultivars, good agronomic practices, post harvest handling, processing and marketing leading to an end-to-end approach. Water source development and recharge of wells through watershed management would also form a part of the technology package (AGRICOOP, 2005).

1.2 Overview

In micro-irrigation, water is carried to the actual root of the plant and not just to the surrounding dirt. It uses pipes, tubes, and a dripper to slowly deliver the water. This method uses much lesser water than normal irrigation and is more efficient and ecological.

In ancient times, a clay pot with holes were filled with water and buried in the ground. Then, a clay pipe was used, which eventually changed into the more common perforated plastic tubing. Even newer developments include a plastic water emitter located where the root sits in which the water drips out. Newer and newer methods make this a valuable contribution to the agriculture world, especially those areas lacking rain and water. Other types of micro-irrigation include the bubbler, where the drip is more spread out, and the micro sprinkler, which is used overhead where the water is emitted in micro-sprays. This is usually in a closed setting such as a greenhouse.

Ideally, the irrigation tube is buried in the dirt, close to the surface. At each plant, the emitter is placed into the tubing (which is perforated). A pump pressurizes the water slowly through the emitters. If drip irrigation is combined with mulching, this form of watering would actually reduce surface evaporation and be quite effective in conservation methods. Drip irrigation can also help reduce foliage diseases that come about with wet and moldy leaves because the water goes directly down to the main root.

Micro-irrigation is used in farms as well as commercial greenhouses. It has proven successful in a commercial sense due to automation. Also, with piping and pressurized pumps, fertilizer can be added to the water. This automates the watering and feeding of plants and is less labor intensive. On land that is hilly or sloped, micro-irrigation can be the answer in avoiding run-off. The cost of micro-irrigation would cost less than leveling the land for any type of farming and can help control erosion. On farms growing crops spaced closely together, such as strawberries, micro-irrigation can help in more direct watering methods. For crops grown under cover, requiring more water, micro-irrigation can help control the flow.

1.3 Design Synthesis

Irrigation pipeline systems are generally described as branching systems. Various branches are given names such as main, sub main, and lateral. Fig 1 shows a typical layout of micro-irrigation system. Choosing the right size main, sub main, and lateral pipe to match the flow rates from the water source is important. Basic components include a pump and power unit, a backflow prevention device if chemicals are used with water, a filter, a water distribution system, and some devices for controlling the volume of water and pressure in the system. If the water source is from a city/municipal/rural water supply, a direct connection is possible.

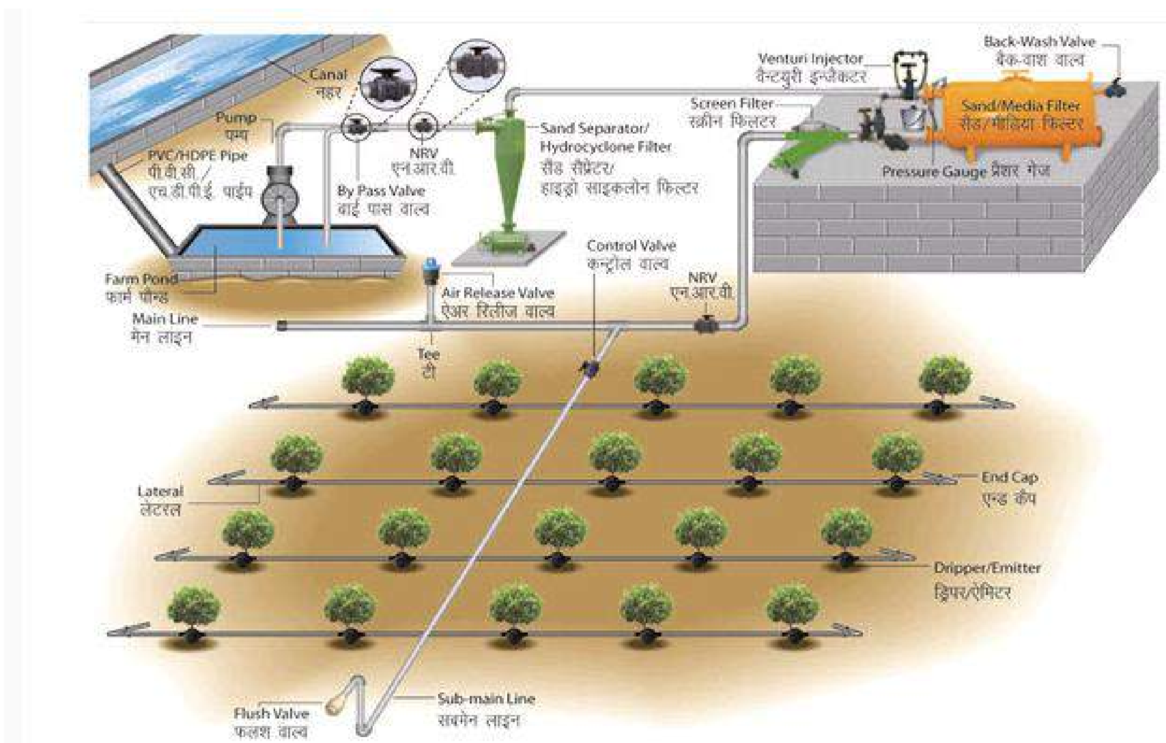

Fig 1. Typical Layout of Micro Irrigation

1.4 Maintenance of Micro Irrigation System

Micro irrigation systems are technically more complex than overhead sprinkler or flood irrigation systems. They require significant maintenance to assure maximum operational efficiency. The performance of a micro-irrigation system may rapidly deteriorate if it is not routinely maintained by:

- o Checking for leaks.
- o Backwashing and cleaning filters.
- o Periodic line flushing.
- o Chlorinating.
- o Acidifying (if necessary).
- o Cleaning or replacing plugged emitters.
- o Evaluating and monitoring system performance

Proper maintenance of a micro-irrigation system will:

- o Extend system life.
- o Improve performance.
- o Minimize shut-down time.
- o Reduce the probability of non-uniform water and fertilizer applications due to emitter plugging.
- o Reduce operating costs.
- o Save water and fertilizer.
- o Improve production.
- o Provide maximum benefits for freeze protection

Before implementing routine or remedial maintenance on a micro irrigation system, test the water source for physical, chemical, and biological properties to determine emitter plugging potential.

It is important to take a representative water sample:

- If the water source is a well, collect the sample after the pump has run for about half an hour.

- If sampling surface water, collect the sample near the center of the source about 1 ft below the water surface.
- Check for water source variability by taking samples several times during the irrigation season.

To accurately measure water pH, alkalinity, dissolved iron, and hydrogen sulfide, analyze well water with a field test kit immediately after sampling.

Use Table 1 to estimate the plugging hazard of irrigation water based on a standard analysis

Table 1. Chemical criteria for plugging potential of micro-irrigation water sources (Pitts, 1990).

Factor	Plugging hazard based on concentration		
	Slight	**Moderate**	**Severe**
Suspended solids[1]	< 50	50 to 100	> 100
pH	< 7.0	7.0 to 7.5	> 7.5
Total dissolved solids[1]	< 500	500 to 2000	> 2000
Iron[1]	< 0.1	0.1 to 1.5	> 1.5
Manganese[1]	< 0.1	0.1 to 1.5	> 1.5
Calcium[1]	< 40	40 to 80	> 80
Hardness as $CaCO_3$[1]	< 150	150 to 300	> 300
Hydrogen sulfide[1]	< 0.2	0.2 to 2.0	> 2.0
Bacteria (#/mL)	< 10,000	10,000 to 50,000	> 50,000

[1]Concentration as milligrams per liter (mg/L) or parts per million (ppm).

1.5 ROUTINE MAINTENANCE OF SYSTEM COMPONENTS

Routine maintenance involves "preventative" practices that all micro-irrigation systems should receive regardless of age. Proper attention to the following will decrease the likelihood of irrigation system failure:

1.5.1 Pumps

• Follow manufacturer's recommendations to maintain submersed turbine or above-ground centrifugal pumps.

• Turbine pumps require little maintenance. If failure does occur, repair requires the removal of the pump, which can be complicated and expensive.

• During the irrigation season, check above-ground pumps at each site visit for: o Excessive or unusual noise or vibration. o Water leakage. o Proper flow rate and pressure. o Intake screen obstructions.

1.5.2 Power units

• Electric motor routine maintenance

o Dirt and corrosion Wipe, brush, vacuum, or blow accumulated dirt from the frame and air passages. Feel for air discharge from the cooling air ports. If the flow is weak, internal passages are probably clogged and require cleaning. Check for signs of corrosion and repaint or repair if necessary. Open the conduit box and check for deteriorating insulation or corroded terminals. o Lubrication Lubricate bearings only when scheduled, if they are noisy, or if they are running hot. **Do not over-lubricate**.

o Heat, noise, and vibrationƒ Feel the motor frame and bearings for excessive heat or vibration. Listen for abnormal noise. Promptly identify and eliminate the source of these problems.

o Winding insulationƒ If records indicate a tendency toward periodic winding failures, check the condition of the insulation with an insulation resistance test.

• Diesel engines

o During the irrigation season, visually check the engine at each site visit for: ƒ Proper oil pressure and coolant temperature. ƒ Fluid (oil, fuel, coolant) leaks or stains. ƒ Excessive noise or vibration.

o Regularly check the engine oil level with the system off.

o Change the following based on the manufacturer's recommendation: ƒ

Engine oil. ƒ

Engine coolant. ƒ

Oil and fuel filters.

o Tune up the engine and take other preventative measures once a year or as the manufacturer recommends.

1.5.3 Water filters Proper water filter performance is critical to minimize emitter plugging. Filters must be periodically cleaned of accumulated particles and debris. Backwashing is a typical cleaning method. A partially clogged filter may reduce system pressure, resulting in reduced and non-uniform water application. Clogged filters also increase pump pressure head and consume extra energy.

• **Schedule filter backwashing either manually based on a time interval or automatically based on pressure differential.**

o If possible, use automatic backwashing. Set the automatic backwash to operate on a 5 to 6 psi pressure differential.

o If backwashing manually, determine cleaning frequency based on the length of time it takes for particles to accumulate.

• **During irrigation periods, inspect screen and disk filters monthly (or more frequently if needed)** by removing the cover and examining the filter element:

o With screen filters, check for tears or extruded material in the screen.

o With disk filters, check for accumulated organic material on the outside of the disks, and check for sand or other particles that may have become wedged between disks.

• Check sand media filters at least twice a year: o Check for appropriate sand level.

o Look for caked material in the media.

o Make sure media has not flushed out during backwash.

o Make sure cavities have not opened up.

• **Routinely inspect all components related to automatic backwashing:**

o Hydraulic tubing.

o Pressure regulators.

o Pressure gauges.

o Control valves.

1.5.4 Chemical injection equipment

• Visually inspect injection equipment components each time a chemical is injected into the irrigation system:

o Hoses.

o Valves.

o Pumps.

o Injector.

• **Be sure to flush the injection system with water following each chemical injection so corrosive chemicals do not remain in the equipment**.

1.5.5 Automatic valves

Automatic diaphragm valves are relatively reliable but require periodic inspection to assure proper operation. If a valve failure goes undetected, the pump or power unit could be damaged or water could be applied where it is not needed.

• Inspect and clean diaphragm valves at least once a year. A valve can usually be cleaned without removing it from the line.

  o Clean deposits that have accumulated on the valve stem.

  o Remove encrustation with a wire brush, a weak acid (like vinegar), or very fine sand paper.

• When a valve is opened, inspect the diaphragm, seat, and o-ring seals. Replace any components that are beginning to wear out.

• Periodically inspect adjustable pressure regulating valves to ensure correct setting.

• If regulating valves are pre-set, check them with a pressure gauge mounted at the regulator, or by attaching a portable pressure gauge to a Schrader valve.

1.5.6 Pressure gauges and flow meters

• Check pressure gauges occasionally to make sure they are working.

o Use high-quality liquid-filled gauges.

o Make sure the range of pressure measured by the gauge covers the operating range of the system.

o Check gauge accuracy by comparing with a new gauge or a standard test gauge.

• Occasionally observe flow meters while the irrigation system is operating.

o Make sure the flow rate observed is reasonable for the system.

o Repair or replace a malfunctioning flow meter as soon as possible.

1.5.7 Field pipe, tubing, and emitters

Visually check irrigation system field components for leaks each time you visit a running system. Leaks can develop in plastic system parts (often resulting from animal chewing) and in hardware components like pipe fittings, emitters, and hose adapters.

• Walk or ride the field, observing or listening for excessive water flow.

• When micro-sprinkler stakes are knocked over, the sprinkler pattern becomes grossly distorted. Check for this problem by surveying emitters as they operate.

1.5.8. Line flushing

Particulate matter not removed by filters accumulates in irrigation pipes and laterals. Chemical precipitation may occur inside pipelines after the irrigation system shuts down. Suspended materials will be carried with the irrigation water, but as the water velocity decreases near the end of lines, particles will settle. If these sediments are allowed to build up, they will eventually plug emitters.

• Periodically flush the entire irrigation pipe system (mainlines, submains, headers, manifolds and lateral lines).

• Manually flush lateral lines by opening only a few at a time. The desired flushing water velocity to remove larger and denser particles is 1 to 2 ft/sec.

1.6 Sprinkle Irrigation

In 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 orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressure and sprinkler spacing the amount of irrigation water required to refill the crop root zone can be applied nearly uniform at the rate to suit the infiltration rate of soil. In sprinkler Irrigation water is applied through a pressurized system. The pressure causes the water to flow out through the sprinkler nozzle. Sprinkler pipe lines are light in weight, hence can be easily transported and installed in the field. They are highly flexible, crack and impact-proof, sustains high pressure and temperature, hence more durable. In this system the water is moved dynamically from the water source through a sprinkler nozzle to a desired height at a high velocity where it breaks up into small droplets and falls on to the soil or crop surface. Due to sprinkling action water wastage is less and it requires less labour than surface irrigation. It can be adapted more easily on sandy soils where infiltration loss is considerably high. Altering the land surface slope for surface methods is always economical.

In sprinkler irrigation water is applied over the crop canopy in form of fine droplets or spray. Sprinkler irrigation keeps soil moisture at its optimum beneficial level giving higher crop yield. Aeration through soil is good so quantity as well as quality of produce is also good. Sprinkler systems have several other uses such as spraying of water for germination, control of soil temperature, control of humidity and frost protection. Several fertilizers and chemicals can be applied quickly and economically.

1.6.1 Adoptability and Limitations of Sprinkler Irrigation

Adoptability

i. Suitable to all types of soils except heavy clay.

ii. Suitable for irrigating crops where the plant population per unit area is very high. It is suitable for oil seeds and cereal and vegetable crops.
iii. Water saving & expensive land levelling is not required
iv. Increase in yield. Saves land as no bunds or ridges are required for ponding or guiding water flow.
v. Less problem of clogging of sprinkler nozzles due to sediment laden water as compared to drip irrigation emitters.
vi. Chemical and fertilizer applications can be easily used with sprinkler systems.
vii. Water conservation, saving of labor, fertilizer and pesticides.
viii. Vegetables, citrus, apple, mango, litchi, and other fruit crops can be protected from fog, frost and high solar radiations.
ix. The water use efficiency is high with proper planning and design of sprinkler irrigation systems.
x. Soil moisture can be maintained at optimum level.
xi. Frequent and light irrigation is possible to get better crop response.

Limitations

i. High initial investment as compared to surface irrigation methods.
ii. The fine-textured soils which have a low infiltration rate cannot be irrigated efficiently.
iii. Sprinkler irrigation is not feasible in hot climate and high windy areas, as major portion of water is lost through evaporation and water distribution is affected due to high wind speed.
iv. High operational costs due to higher energy requirements.
v. Not suitable for crops that require ponding water. However, research experiments on paddy crops have given promising results.
vi. In humid regions, crops prone to diseases due to moist environment.
vii. Water with impurities and sediments may damage the system.

1.6.2 Types of Sprinkler Irrigation Systems

Sprinkler irrigation systems may be classified as portable, semi-portable, semi-permanent, or permanent. On the basis water application the sprinkler systems are classified into the following two major types:

1. Rotating head or revolving sprinkler system.

2. Perforated pipe system.

1) Rotating head

Small size nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe and the lateral pipes are usually laid on the ground surface. They may also be mounted on posts above the crop height and rotated through 90^o, to irrigate a rectangular strip. In rotating type sprinklers, the most common device to rotate the sprinkler heads is with a small hammer activated by the thrust of water striking against a vane connected to it. Fig. 2. Shows the different types of rotating head sprinkler irrigation systems.

Fig.2. Rotating Head Sprinkler Irrigation System

2) Perforated pipe system

This method consists of drilled holes or nozzles along their length through which water is sprayed under pressure. This system is usually designed for relatively low pressure (1 kg/cm^2). The application rate ranges from 1.25 mm to 50 mmh^{-1} for various pressures and spacing.

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

(i) Portable system: A portable system has portable mainlines, sub-mains, laterals, and a portable pumping plant. The entire system can be moved from field to field. Fig. 3. Shows the fully portable sprinkler irrigation system.

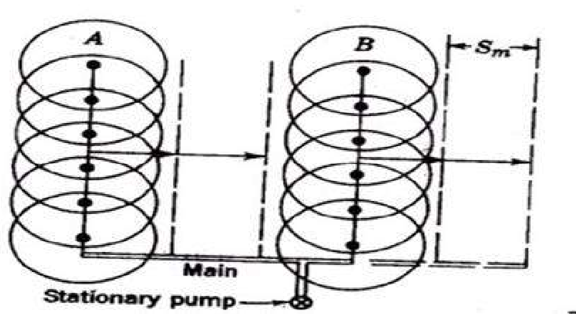

Fig 3. Portable sprinkle irrigation system

ii) Semi-portable system

A semi-portable system is similar to a fully portable system except that the location of water source and pumping plant is fixed. Such a system may be used on more than one field where there is an extended mainline, but may not be used on more than one farm unless there are additional pumping plants.

iii) Semi-permanent system

A semi-permanent system has portable lateral lines, permanent mainlines, and a stationary water source and pumping plant. The mainline are usually buried, risers are (located at suitable intervals) to connect with laterals.

iv) Permanent system

A fully permanent system has buried mainlines, sub-mains, and laterals with a stationary pumping plant and/or water source. Sprinklers are permanently located on each riser. Such systems are costly and are suited to automation.

v) Solid set system

A solid set system has enough laterals to eliminate their movement. The laterals are installed in the field early in the crop season and remain for the season.

vi) Set-move irrigation systems

Set-move sprinkle systems are moved from one set (irrigation) position to another by hand or mechanically. Set-move systems remain stationary when water is applied. When the desired amount of water has been applied, the water is shut off and the sprinkler laterals are drained and moved to the next set position. When the move is complete the water is turned on and irrigation resumed at the new set position. This sequence is repeated until the entire field has been irrigated. Set-move systems commonly have a single mainline laid through the centre of the field with one or more laterals on each side of the mainline.

a) Hand-move

In hand-move system laterals are moved by uncoupling, picking –up, and carrying sections of lateral pipe by hand to the next set position where the lateral sections are reconnected. Earlier hand-move sprinkler laterals were made up of aluminium now these are replaced with HDPE of 50 to 150 mm(2 to 6 in) in diameter, and 6, 9, or 12 m (20, 30, or 40 ft) long are difficult to handle and may not provide proper spacing for the common sprinkler sizes.

b) Tow-move

Tow-move sprinkler systems are the least expensive type of mechanically moved set-move system. Each section of a tow-move lateral has skids or wheels so that the entire laterals can be pulled to the next set position. Usually a tractor is hooked to the mainline end of the lateral and the lateral is dragged in the other direction across the mainline in an opposite S-shaped curve. The moves are made easier by buried mainlines.

Tow-move system are not used extensively because shifting of lateral is tedious, it requires careful attention, and also damages crops. Tow-move systems are suitable to forage and row crops.

c) Side-roll

A side-roll or wheel-move system, like the one is an extremely popular type of mechanically moved set-move system. Each section of pipe in a side-roll lateral has a wheel, with the pipe serving as the axle of the wheel. A gasoline engine and transmission with a reverse gear at the centre or the end of the lateral supplies the power needed to roll the lateral, which may be as long as 800 m (about one-half mile), from one set position to the next. The lateral is commonly 100 or 125 mm (4 or 5 in) in diameter. Each lateral section is usually 12.2 m (40 ft) long with a wheel at its centre and a sprinkler mounted on a short riser at one end. Often the sprinklers have self – levellers to "right" the sprinkler when the lateral is stopped so that the riser is tilted" from its upright position. A drain valve that opens automatically when there is a loss of pressure is usually located opposite each rise. This allows the lateral to be quickly drained and permits moving of lateral with a minimum time loss. The most common spacing along the mainline is 18.3 m (60 ft). The Fig. 4 shows a side-roll lateral sprinkler system used on a potato field.

Fig 4. Side roll lateral sprinkle system

1.6.3 Components of a Sprinkler System

Sprinklers, laterals, sub-mains, and mainlines are the primary components of a sprinkler irrigation system. Sprinklers spread water as "rainlike" droplets over the land surface. Laterals convey water from the mainline and sub-main to the sprinklers. Mainlines convey water from the water source to the sub-mains and laterals. Fig.5. shows the component of a portable sprinkler irrigation system. A sprinkler system usually consists of the following components.

i) A pump unit

ii) Tubing's- main/sub-mains and laterals

iii) Couplers

iv) Sprinkler head

v) Other accessories such as valves, bends, plugs and risers.

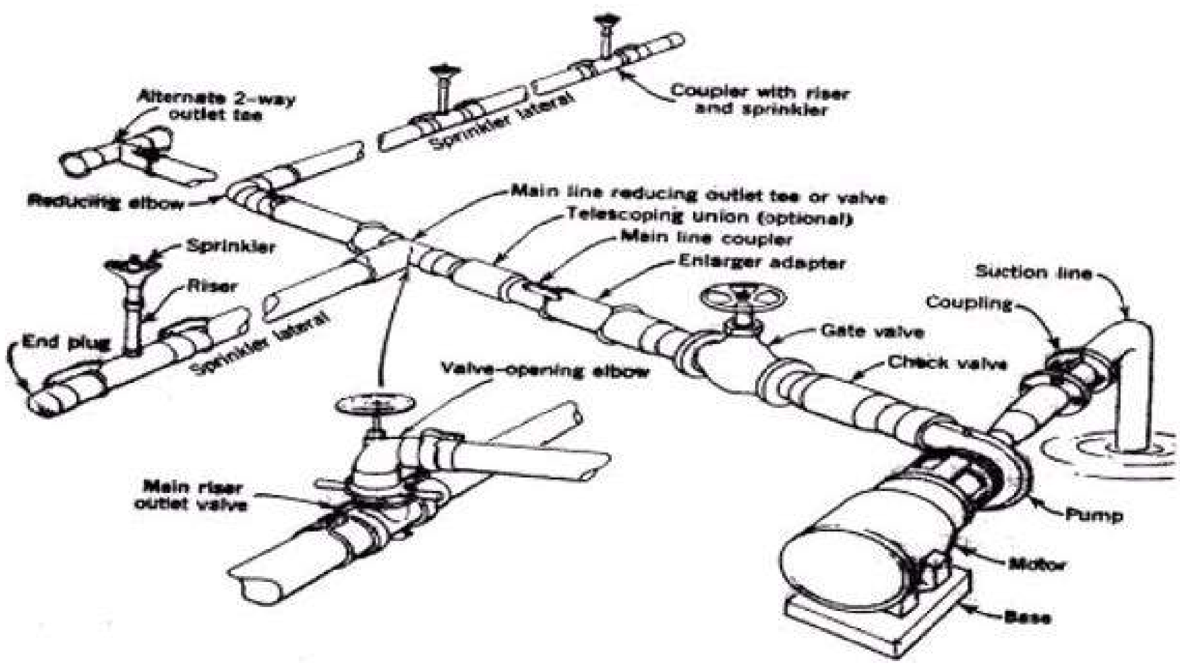

Fig 5. Components of Sprinkle Irrigation System

i) Pumping unit

Sprinkler irrigation systems distribute water by spraying it over the fields. The water from the source (ground water / surface water) is pumped under pressure to sprinkler system. The pressure created through pump forces the water through sprinklers or through perforations or nozzles in pipelines and then forms a spray. A high speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than eight meters. For pumping water from deep wells or more than eight meters, a turbine submersible pump is used. The driving unit may be either an electric motor or an internal combustion engine.

ii) Tubings

The tubing consists of mainline, sub-mains and laterals. Main line conveys water from the source and distributes it to the sub-mains. The sub-mains convey water to the laterals which in turn supply water to the sprinklers. Aluminum or PVC or HDPE pipes are generally used for portable systems, while steel pipes are usually used for centre-pivot laterals. Asbestos, cement, PVC and wrapped steel are usually used for buried laterals and main lines.

iii) Couplers

Couplers are used for connecting two pipes and uncoupling quickly and easily. Essentially a coupler should provide

a) a reuse and flexible connection

b) not leak at the joint

c) be simple and easy to couple and uncouple, and

d) be light, non-corrosive, and durable.

iv) Sprinkler head

Sprinkler head distribute water uniformly over the field without runoff or excessive loss due to deep percolation. Different types of sprinklers are available. They are either rotating or fixed type. The rotating type can be adapted for a wide range of application rates and spacing. They are effective with pressure of about 10 to 70 m head at the sprinkler. Pressures ranging from 16 to 40 m head are considered the most practical for most farmers.

Fixed head sprinklers are commonly used to irrigate small lawns and gardens. Perforated lateral lines are sometimes used as sprinklers. They require less pressure than rotating sprinklers. They release more water per unit area than rotating sprinklers. Hence fixed head sprinklers are adaptable for soils with high intake rate. Fig. 6. Shows the rotating head sprinkler head.

Fig 6. Sprinkle Head

v) Fittings and accessories: Fig 7 shows different types of sprinkler fittings and accessories. The following are some of the important fittings and accessories used in sprinkler system.

a) Water meters: It is used to measure the volume of water delivered. This is necessary to operate the system to supply the required quantity of water.

b) Flange, couplings and nipples are used for proper connection to the pump, suction and delivery.

c) Pressure gauge: It is used to measure operating pressure of sprinkler system. to ensure application uniformity, the sprinkler system is operated at desired pressure.

d) Bend, tees, reducers, elbows, hydrants, butterfly valve and plugs are optimal components of a sprinkler system. They are used as per requirements.

e) Fertilizer applicator: Soluble chemical fertilizers can be injected into the sprinkler system and applied to the crop. The fertilizer applicator consists of a sealed fertilizer tank with necessary tubing's and connections. A venturi injector is connected with the main line, which creates the differential pressure suction and allows the fertilizer solution to flow in the main water line.

Fig 7. Different fitting and accessories

1.6.4 Sprinkler Performance Evaluation

The basic purpose of sprinkler irrigation is to apply uniform depth of water to the field crop. The water distribution pattern of a sprinkler nozzle is tested with the sprinkler operating individually under a set of specific conditions. Operating pressure and nozzle geometry (i.e., nozzle opening size, shape, and angle) are the primary factors that control the operation of sprinklers. The performance of a sprinkler is described by its discharge, distance of throw, distribution pattern, application rate and droplet size.

Sprinkler Discharge, Distance of Throw and Application Rate

i) **Sprinkler Discharge:** Sprinkler discharge is the volume of water passing out of the sprinkler nozzle. Common units for sprinkler discharge are liters per minute (1/min) and gallons per minute (gpm) in the SI and English systems, respectively. Equation 1 can be used to relate sprinkler discharge to operating pressure and nozzle geometry.

$$Q = \sum_{l=1}^{n} K\, C_i\, A_i\, P_i^{x_i} \qquad \text{………………….(1)}$$

Where,

Q = sprinkler discharge;

n = number of nozzles;

K = constant that depends on unit used;

C = coefficient that depends on shape and roughness of opening in nozzle i;

A = cross-sectional area of the opening in nozzle i;

P = operating pressure in nozzle i;

x = exponent for nozzle i.

Thus, discharge of a multi nozzle sprinkler is the sum of the nozzle discharges.

Values of C and for each nozzle and normally determined empirically. Since is about 0.5 for most sprinklers, higher pressures and/ or larger nozzle openings will increase sprinkler discharge. Sprinkler manufactures commonly publish tables of pressure and discharge data for various nozzle diameters. Sprinkler discharge is not related to nozzle angle.

ii) **Distance of Throw:** The spacing between adjacent sprinklers depends, in part, on the distance sprinklers throw water. Spacing usually increases as the distance of throw rises.

The operating pressure, and size, shape and angle of the nozzle opening determine the distance a sprinkler throws water. Distance of throw also tends to increase as nozzle size increases (other things remaining constant). Nozzles opening shapes that create smaller diameter droplets tend to wet a smaller area than nozzle that emit larger droplets. Distance of throw usually increases and then declines as nozzle angle rises above horizontal. Sprinkler manufactures commonly publish wetted diameter or other measures of distance of throw for different operating pressures, and nozzle sizes, shapes, and angles.

iii) Application rate: Application rate is an extremely important parameter that is used to properly match sprinklers to the soil, crop, and terrain on which they operate. When sprinkler application rates are too high, runoff and erosion can occur. Application rate has dimensions of length per unit time. The average application rate of an individual sprinkler can be computed using Eq. 2.

$$A = K\frac{Q}{a} \quad \text{.....................................(2)}$$

Where

A = application rate (mmh^{-1}, inh^{-1});

Q = sprinkler discharge ($Lmin^{-1}$, $gmin^{-1}$)

a = wetted area of sprinkler ($m,^2$ ft^2)

K = unit constant (K= 60.0 for A in mm/h, Q in $Lmin^{-1}$, and a in m^2.

K = 96.3 for A in inh^{-1} , Q in $gmin^{-1}$, and a in ft^2).

When several identical sprinklers are spaced in a L by S grid. Eq. 3 can be used to compute the average application rate.

$$A = \frac{KQ}{LS} \quad \text{....................................(3)}$$

where

A = application rate (mm/h, in/h);

Q = discharge of individual sprinklers

L = distance between sprinklers along the lateral (m)

S = spacing between adjacent sprinkler lines or lateral set positions (m)

K = K in Eq. 2.

For most sprinklers, variation in operating pressure has little, if any, effect on the average application rate of an individual sprinkler. When operating pressure increases, for example, the increase in Q tends to be offset by the increase in wetted area. The average application rate of several identical overlapping sprinklers, however, tends to be directly related to operating pressure, since L and S remain constant as Q increases. This is also true for the average application rate beneath a sprinkler lateral.

The average application rate for an individual sprinkler varies widely depending upon nozzle geometry. Deflector plate sprinklers, for example have relatively high average application rates, since they wet a much smaller area than relatively high average application rates, since they wet a much smaller area than do other types of sprinklers. Conversely, conventional impact sprinklers are normally designed to achieve the maximum wetted area, and thus lowest possible average application rate. Nozzle opening shapes that create smaller droplets and wet a smaller area tend to have the highest average application rates. Average application rate will usually decrease and then increase as nozzle angle increases above horizontal. Increasing nozzle diameter usually increases the average application rate, since Q normally increases more rapidly than wetted area.

iv) **Droplet Size** Droplet size is an important factor affecting the formation of ‘‘seals’’ on bare soil surfaces that restrict water movement into the soil. Because small droplets possess less power when they impact the soil surface, ‘‘seals’’ that limit infiltration form more slowly than with larger droplets. For these reasons, it is sometimes possible to reduce runoff and erosion by converting from sprinklers that emit large droplets to ones with smallest droplets.

Droplet size is especially important when sprinklers must operate in winds. Distribution patterns from sprinklers that emit smaller droplets are more subject to wind distortion and lower application uniformity. In addition, increased losses due to wind drift usually occur with small droplet sprinklers.

Higher operating pressures normally increases the volume of water applied as smaller droplets while decreasing the volume of larger droplets. A similar, but a significantly smaller effect occurs on the larger droplets (not on the volume of water) as nozzle opening size is decreased. Nozzle opening shape can have an important effect on droplet size while nozzle angle has little, if any effect.

v) Distribution pattern

i) Uniformity coefficients: A measurable index of the degree of uniformity obtainable for any size sprinkler operating under given conditions has been adopted and is known as the uniformity coefficient (C_u). This uniformity coefficient is affected by the pressure nozzle size relations, by sprinkler spacing and by wind conditions. The coefficient is computed from field observations of the depths of water caught in open cans placed at regular intervals within a sprinkled area. It is expressed by the equation developed by Christiansen (1942):

$$C_u = 100(1.0 - \frac{\sum X}{mn}) \qquad \text{..........................(4)}$$

in which

C_u = coefficient of uniformity

m = average value of all observations (average application rate), mm

n = total number of observation points

X = numerical deviation of individual observation s from the average application rate, mm.

A uniformity coefficient of 100 per cent (obtained with overlapping sprinklers) is indicative of absolutely uniform application, whereas the water application is less uniform with a lower percentage. A uniformity coefficient of 85 per cent or more is considered to be satisfactory.

ii) Pattern efficiency: The pattern efficiency (also known as distribution efficiency) can be calculated after obtaining the total depths at each of the grid point. The minimum depth is calculated considering average of the lowest one fourth of the cans used in a particular test. Pattern efficiency is given by

$$P_e = \frac{min.\,depth}{average\ depth} \times 100 \qquad \text{..........................(5)}$$

The pattern efficiency is useful in calculating the average depth to be applied for a certain minimum depth. The pattern efficiency is influenced by the wind conditions. Application

$$\text{Application efficiency} = \frac{\text{Min.rate caught}}{\text{Average rate applied}} \quad \text{……………………(6)}$$

1.6.5 Parameters for Design of Sprinkler Irrigation System

The basic objective of sprinkler irrigation system is to apply uniform depth of water at predetermined application rate. The sprinkler irrigation system should be designed properly to achieve high irrigation efficiency. The inventory of resources and climatic conditions of the field area are primarily required for the design of sprinkler irrigation system.

A) Inventory of resources and other parameters

Land: Land is often a major factor in irrigation system design as it influences the selection of sprinkler device, irrigation efficiency, costs of land development, labour requirements, range of possible crops, etc. The major factors of land which have a special bearing on sprinkler irrigation design are: slope, infiltration rate, effective soil depth, texture & structure of soil and size & shape of field.

Water: The source of water supply for sprinkler irrigation can be surface water (river, canal, pond etc.) or ground water (a tube well or open well). Adequate water availability & quality parameters play an important role in the design of sprinkler irrigation system.

Climate: Important climatic data required are solar radiation, temperature, relative humidity, evapotranspiration rate, precipitation or rainfall and wind speed. These climatic parameters are required to estimate peak consumptive use rate as well as total seasonal evapotranspiration of crop(s).

Source of power: Electricity, diesel, solar, wind and biofuels are used to pump water from the source. The selection of pump depends on type of power used to operate pump.

B) Soil water parameters

Net depth of water application

The depth of water application is the quantity of water, which should be applied during irrigation in order to replenish the water used by the crop during evapo transpiration. The difference between field capacity and permanent wilting point will give the available soil moisture (water holding capacity), which is the total amount of water that the crop can use. Depending on the crop sensitivity to stress, the soil moisture should be allowed to be depleted only partially. For most field crops, a depletion of 60 to 65% of the available moisture is acceptable. This is the moisture that will be easily available to the crop without causing undue stress. The maximum net depth to be applied per irrigation can be calculated, using Equation 7.

$$d_{net} = (\theta_{FC}-\theta_{WP}) \text{ x } D_{rz} \text{ x } P \quad \text{.....................................(7)}$$

where,

d_{net} = readily available moisture or net depth of water application per irrigation for the selected crop, mm

θ_{FC} = soil moisture at field capacity, mm/m

θ_{WP} = soil moisture at the permanent wilting point, mm/m

D_{rz} = the depth of soil that the roots exploit effectively (m)

P = the allowable portion of available moisture permitted for depletion by the crop before the next irrigation

In order to express the depth of water in terms of the volume, the area proposed for irrigation is multiplied by depth.

$$\text{Volume of water to be applied } (m^3) = 10 \text{ x A x d} \quad \text{.....................(8)}$$

where,

A = area proposed for irrigation, ha

d = depth of water application, mm

Example 14.1

A twenty hectare area has medium texture loam soil grown with Wheat crop peak. Daily water use of wheat crop is 6.2 mm day^{-1}. The available soil moisture ($\theta_{FC} - \theta_{WP}$) is 120 mm m^{-1}. The allowable soil moisture depletion is 50%. The crop root zone depth (D_{RZ}) is 0.8 m. Soil infiltration rate is 6 mm h^{-1}. The other climatic data are: average wind speed 10 km h^{-1}. Determine the maximum net depth of water application.

Solution:

Using Equation 7, net depth of water application per irrigation for the selected crop is computed as

d_{net} = 120 x 0.8 x 0.5 = 48 mm

For an area of 20 ha, net application of 9600 m^3 (10 x 20 x 48) of water will be required for irrigation to bring the root zone depth of the soil from the 50% allowable depletion level to the field capacity (Equation 8).

Irrigation frequency

Irrigation frequency refers to the number of days between irrigations during periods without rainfall. Irrigation frequency depends on crop, soil and climate. After establishing the net depth of water application, the irrigation frequency at peak moisture rate of crop should be determined using the following equation 9.

Irrigation frequency (F) = d_{net} / wu ----(9)

Where, F = irrigation frequency, days; d_{net} = net depth of water application, mm

wu = peak daily water use, mm day^{-1}.

Example 14.2

The peak demand for wheat was estimated as 6.2mm day^{-1}. Using the data available in Example 14.1, determine the irrigation frequency.

Solution:

Irrigation Frequency (F) =48 mm / 6.2 mm/day = 7.7 days

The irrigation system should be designed to provide 48 mm in every 7.7 days. For practical purposes, fractions of days are not used for irrigation frequency. Hence the irrigation frequency in this example is taken as 8 days. The corresponding net depth of d_{net} of water application

d_{net} = 6.2x 8 = 49.6 mm

The moisture depletion

= 49.6/(120 x 0.8) = 0.52

The question arises as to whether the irrigation system should apply the d_{net} in 8, 7, 6, right down to 1 day. This choice will depend on the flexibility the farmer would like to have and his/her willingness to pay the additional cost for different levels of flexibility. If irrigation is to be completed in 1 day, the system becomes idle for the remaining 7 days, and the cost of the system would be exorbitant, since larger sizes of irrigation equipment would be required. On the other hand, for all practical purposes and in order to accommodate the time for cultural practices (spraying etc), it is advisable that irrigation is completed in less than the irrigation frequency. In the case of our example, 7 days irrigation and 1 day without irrigation is considered adequate. The 7 days required to complete one irrigation in the area under consideration is called the irrigation cycle.

Gross depth of water application

The gross depth of water application (d_{gross}) equals the net depth of irrigation divided by the farm irrigation efficiency. It should be noted that farm irrigation efficiency includes possible losses of water from pipe due to leakage or from other sources.

$$d_{gross} = d_{net}/E \qquad \text{-------------------(10)}$$

Where E = the farm (or unit) irrigation efficiency.

The farm irrigation efficiency of sprinkler systems varies from climate to climate.

C) System capacity

The next step is to estimate the system capacity. The system capacity (Q), can be estimated using Equation 14.5 given below

$$Q = (10 \times A \times d_{gross}) / (I \times Ns \times T) \qquad \text{---------------- -----(11)}$$

Where Q = system capacity, $m^3\ h^{-1}$; A = area, ha; d = gross depth of water application, mm; I = irrigation cycle, days; Ns = number of shifts per day; T = irrigation time per shift, h.

Example 14.4

The irrigation system operates for 11 hours per shift. Two shifts per day during peak demand is used in each irrigation cycle of 7 days to complete irrigation in 20 ha area. Determine the capacity of irrigation system.

Solution: A=20 ha, d_{gross}=66.13 mm, N_s=2, I = 7 days, T =11 h.

Substituting values in Equation 10, the system capacity is

$Q = (10 \times 20 \times 66.13) / (7 \times 2 \times 11)$

$Q = 85.88\ m^3\ h^{-1}$

D) Sprinkler selection and spacing

Based on specifications furnished by the manufacturers of the equipment the sprinkler system components are selected. The important parameters include in selection are diameter of coverage, pressure available, sprinkler discharge, combination of sprinkler spacing and lateral moves, application rate suiting to soil and wind conditions. The required discharge of an individual sprinkler is a function of the water application rate and the two-way spacing of the sprinklers. The maximum application rate for different types of soils at different land slopes is given in Table 1.

Discharge from a sprinkler is computed by

$$q = \frac{S_1 \times S_m \times I}{3600} \qquad \text{-- (12)}$$

where,

q = required discharge of individual sprinkle, Ls^{-1}

S_l = spacing of sprinklers along the laterals, m

S_m = spacing of laterals along the main, m

I = optimum application rate, mm h^{-1}

Table 1.

Maximum application rate for different type of soils at different land slopes, cm h^{-1}

Soil texture and profile	**0 to 5% slope**	**5 to 8 % slope**	**8 to 12 % slope**
Coarse sandy soils to 2 m	5.10	3.75	2.54
Coarse sandy soils over more compact soils	3.75	2.54	1.9
Light sandy loams to 2 m	2.54	2.03	1.5
Light sandy loams over more compact soil	1.9	1.27	1.02
Silt loam 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

Example 14.5

A sprinkler system 18 m spacing along the main and 12 m along the laterals is used to irrigate crop grown on coarse sandy soil over more compact soil land slope of 3 per cent. Twenty sprinklers are used to irrigate field. Determine the total system capacity.

Solution:

$$q = \frac{s_1 \times s_m \times I}{3600}$$

Discharge from a single sprinkler

=12 m, = 18 m, I =3.75 cm h^{-1}= 37.5 mm h^{-1}, q = 0.75 L s^{-1}

System capacity (q) = 20 × 0.75 =15 L s^{-1}

E) Height of sprinkler riser pipes

Sprinklers are located just above the crops to be irrigated and therefore, the height of the risers depends upon the maximum height of the crop. To avoid excessive turbulence in the riser pipes the minimum height of riser is 300 mm for 25 mm diameter and 150 mm for 15 mm to 20 mm diameter. In general, 900 mm long G.I. pipe of 25mm diameter is used.

F) Sprinkler spacing

The uniformity of water distribution from sprinklers depends on the pressure of water, wind velocity, rotation of sprinklers, spacing and nozzle diameter. The spacing of sprinklers in a lateral and the laterals spacing are adjusted considering all these parameters. Generally at satisfactory desired operating pressure the water distribution beneath sprinkler head accumulate more and depth decreases gradually with distance from the sprinklers.

Normally sprinklers are spaced at 50 per cent of the diameter of the coverage by an individual sprinkler. If there is a wind of considerable speed, the spacing between sprinklers is reduced. Table 2 is used to adopt sprinkler spacing under windy condition. This overlap is desired to achieve uniform application on water.

Table 2. Spacing of sprinklers for different wind speed.

Sl.No.	Average wind speed	Spacing
1	No wind	65% of the water spread area of a sprinkler
2	0-6.5 km h^{-1}	60% of the water spread area of a sprinkler
3	6.5 to 13 km h^{-1}	50% of the water spread area of a sprinkler
4	Above 13 km h^{-1}	30% of the water spread area of a sprinkler

Quality Control in Micro Irrigation Components

1.1 Institutions Framing Standards

At the international level there are several institutions formulating standards for crop irrigation. Some of these are

i) Bureau of Indian Standards (BIS)
ii) British Standards Institute (BSI)
iii) American Society of Testing Materials (ASTM)
iv) International Organization of Standards (ISO)
v) American Society of Agricultural Engineers (ASAE)
vi) American National Standards Institute (ANSI)

The Bureau of Indian Standards

Standardization of any product process or service in India is carried out by the Bureau of Indian Standards (BIS). The Government of India established Indian Standards Institution (ISI) in January 1947. With fast pace of development and industrialization the existing structure was found to be inadequate. ISI was therefore restructured with statutory authority and Bureau of Standards Act was passed in December 1986. The BIS became functional from April 1987. Bureau has several technical divisions to look after the Indian Standards, of which one of the important divisions has been Agriculture and Food Division. This division has several technical committees. FAD-35 was one of such committees that formulated the standards for drip irrigation. This was later modified as Irrigation and Farm Drainage Equipments and System Sectional Committee FAD-54.

1.2 Testing of Micro-irrigation Components for Standards

The parameters needed for testing of micro-irrigation components are described below:

i) Melt Flow Index: This test is used to determine the right combination of materials used to manufacture laterals and other plastic materials. The melt flow indexer is used to conduct this test.

ii) Tensile Strength: This test is carried out for a special shaped piece obtained by a dumb bell and elongation is tested at 27^{o}C temperature by a universal testing machine.

iii) Environmental Stress Cracking Resistance: This test indicates the strength of material against breakage of poly-tube/lateral under various environmental conditions. The water bath with thermostatic control, vernier calipers, ball ended micro meter and forced air circulation oven maintained at 50 ^{o}C ± 3 ^{o}C capable of reestablishing that temperature in 5 minutes are required for this test.

iv) Reversion test: This test is conducted to study the internal stress during processing in the lateral. A pipe of about 200 m long is subjected to a temperature around 100 ^{o}C for about an hour and cooling to the room temperature. The changes in the dimensional should not be more than 3%. Thermostatic oven is required for this test.

v) Carbon Black Content: The concentration of carbon black is essential to ascertain that the lateral can provide appropriate UV stability. The carbon black should have specified density. The manufacturer is permitted to add carbon black to an extent of 10%. Carbon content analyzer with ultra pure nitrogen cylinder is required to determine the carbon black content.

vi) Carbon Dispersion: Proper dispersion of carbon black is essential for good UV stability of lateral pipes. A micro scope with magnifier (200 times magnification) is needed for determining carbon dispersion.

vii) Hydraulic Characteristics: Internal Pressure Creep Rupture of poly-tubes is required to conduct hydraulic characteristics of drip pipes. This essentially consists of two important tests: a) Acceptance test and b) Quality test. Acceptance test is carried out at a lower temperature for test duration of a given time (say 1 h) under an induced stress as specified by prevailing standards. The quality test is conducted to test the standard of material and procedure of pipe material and carried out at a higher temperature with longer duration (say 100 h) to stand the specified induced stress of 2.5 MPa and 20 ^{O}C for 1 h at induced stress of 6.9 MPa. Pressure Creep Rupture tester is required to conduct this test.

1.3 Indian Standards for MI Components

Indian standards published by BIS on various components of micro irrigation system are given in Table 1. These standards are prepared based on corresponding International standards with suitable modifications to meet Indigenous requirements.

Drip Laterals: Polyethylene pipes for irrigation laterals should withstand the internal pressure creep rupture test which is conducted at a temperature of 70^{0} C for 100 h at induced pressure of 2.5 MPa and 20^{0} C for 1 h at an induced stress of 6.9 MPa. Maximum longitudinal reversion of the pipe after keeping it at a temperature of 100 ± 2^{0} C for 1 h shall be in the range of ± 3%. Similarly tensile strength and elongation at break at 27 ± 2^{0} C and testing speed of 100 mm/min. ± 10 mm/ min shall not be less than 10 MPa and 350% respectively. Pipe for laterals shall also withstand the accelerated test for susceptibility to environmental stress cracking.

Emitting Pipe: Uniformity of emission of emission rate should not deviate from declared value by more than ± 5% for category A and ± 10% for category B pipes. Emitting pipe shall withstand the hydrostatic pressure 1.8 times the recommended working pressure at ambient temperature for 1 h and at temperature of 60 ± 2^{0} C for 48 h without any leakage and any permanent deformation or damage. Emitting pipe shall also bear the tensile forces of 180 N when applied for 15 minutes at elevated temperature of 50 ± 2^{0} C joint between fitting and emitting pipe shall not come out on pull of 180 N when applied for 1 hour.

Table 1. Indian standards published by BIS on various components of micro irrigation system

1) Drip irrigation system components	**Standards**
i) Main and sub-main pipes a) PVC pipes b) HDPE pipes	 IS 4985 : 2000 IS 4984 : 1995
ii) Lateral: High quality PE lateral in 12 mm and 16 mm	IS 12786 : 1989
iii) Emitting pipe system	IS 13488 : 1992
iv) Emitters/drippers (Pressure and non pressure compensating types)	IS 13487 : 1992
v) Micro-tubes	IS 14482 : 1998
vi) Micro-sprayers	IS 14605 : 1998
2) Filteration system i) Strainer type filters ii) Media filters iii) Hydro-cyclone filters	 IS 12785 : 1994 IS 14606 : 1998 IS 14743 : 1999
3) Fertigation i) Fertilizer and chemical injection system part I Venturi injectors	IS 14483(Part I):1997
4) Others i) Pressurized irrigation equipments terminology ii) Design, installation and field evaluation of micro-irrigation system- code of practices iii) Recommended criteria for adoptability of different irrigation methods iv) Prevention and treatment of blockage problem in drip irrigation system- code of practice	 IS 14178 : 1994 IS 10799 : 1999 IS 11711 : 1986 IS 14791 : 2000

Main and Sub-main pipe

The material used for pipe is polyvinyl chloride (PVC). The different grades of resins are available for various usages and these are selected according to the essential properties such as density, melt flow index/K-value, molecular weight distribution, etc. The BIS specifications of plastic materials in various applications are given in Table 21.2. For PVC pipe, the base material density of the resin should be between 1.40 and 1.46 g/cc, and K-value minimum 64 and other additives which may help the manufacturing process and good finish. For HDPE pipes, base material density of 0.9405 to 0.9460 g/cc and Melt Flow Index 0.4 to 1.1 g/10 min at 190^0C/5 kg/load are desired. Carbon black should be added to the tune of 2-3% and should be well dispersed for long service life of lateral. The pipe shall not have any detrimental effect on the composition of the water flowing through these pipes.

Emitters (IS 13487 : 1992): The smallest measured flow path dimension shall not be smaller than the dimension declared by the manufacturers. Emitters shall be tested to resistance to hydrostatic pressure and leakage at pressure twice the maximum working pressure. The mean emission rate of 25 randomly selected emitters shal not deviate from the nominal discharge rate by more than ±5% for category A and ±10% for category B emitters. When inserted on the lateral emitter shall also bear a pull of 40 N for on-line emitters and a radial force of 500 N for inline emitters.

Micro-tubes (IS 14482 : 1997): Micro tubes shall conform to the requirements for longitudinal reversion, tensile strength and environmental stress cracking test for polythene laterals. In addition micro tube shall also withstand hydrostatic pressure 1.2 times the maximum operating pressure for 1 h without suffering damage and pulling out from assembly.

Micro-sprayers (IS 14605 : 1998): Micro-sprayers shall bear the hydrostatic pressure of 1.2 times the maximum working pressure for a period of 1h without any damage, leakage and pull out from assembly. Threaded connections shall withstand a torque of 20 Nm for metal to metal contact and 4 Nm for plastic to plastic or plastic to metal contact without showing any sign of damage. Upper and lower specification limits for uniformity of flow rate are ±10% for regulated sprayers and ±7% for non regulated sprayers. In case of regulating type micro sprayer, the maximum and minimum flow rates shall not deviate by more than ±10% from the nominal flow rate within the regulation range and average flow rate shall not deviate by more than ±2.5% from the nominal flow rate, the effective diameter of coverage shall conform to the value supplied by the manufacturer within a permissible deviation of ±10%. After operating the micro sprayer for 1500 h, the measured flow rate of test sprayer shall remain within ±10% of the initial flow rate and sprayer shall not show any visible defect.

Design and Maintenance of Polyhouse

INTRODUCTION

In greenhouses, the choice of structural materials is linked to: (i) their availability and cost; (ii) their technical characteristics depending on the greenhouse to be built (use of wood, steel); (iii) the performance required by the greenhouse depending on the crops to be grown; (iv) the local climate; and (v) the local conditions in terms of experience and creativity. The materials commonly used to build frames for greenhouse are Wood, Bamboo, Steel, Galvanized iron pipe, Aluminum and Reinforced concrete (RCC). The selection of above materials is based on their specific physical properties, requirements of design strength, life expectancy and cost of construction materials.

WOOD

Wood and bamboo are generally used for low cost poly-houses with straight roof structure (fig. 1) due to difficulty and high cost associated with its use on curved sections. In low cost poly-houses, the wood is used for making frames consisting of side posts and columns, over which the polythene sheet is fixed. The commonly used woods are pine and casuarina, which are strong and less expensive. In pipe-framed poly-houses, wooden battens can be used as end frames for fixing the covering material. In tropical areas, bamboo is often used to form the gable roof of a greenhouse structure. Wood must be painted with white colour paint to improve light conditions within the greenhouse. Care should be taken to select a paint that will prevent the growth of mold. Wood must be treated for protection against decay. Chromated copper arsenate and ammonical copper arsenate are water based preservatives that are applied to the wood that may come into contact with the soil. Red wood or cypress (natural decay resistance woods) can be used in desert or tropical regions, but they are expensive.

Fig. 1 Wooden framed polyhouse

GALVANISED IRON (GI), ALUMINUM, STEEL AND REINFORCED CEMENT CONCRETE

GI pipes, tubular steel and angle iron are generally used for side posts, columns and purlins in greenhouse structure, as wood is becoming scarce and more expensive. In galvanising operation, the surface of iron or steel is coated with a thin layer of zinc to protect it against corrosion. The commonly followed processes to protect against corrosion are:

i. **Hot dip galvanising (hot process) process:** The cleaned member is dipped in molten zinc, which produces a skin of zinc alloy to the steel.
ii. **Electro-galvanising (cold process) process:** The cleaned member is zinc plated similar to other forms of electro-plating. The galvanising process makes the iron rust proof, to eliminate the problem of rusting of structural members.

Aluminum and hot dipped GI are comparatively maintenance free. In tropical areas, double dipping of steel is required, as single dip galvanising process does not give a complete cover of even thickness to the steel. Aluminum and steel must be protected by painting with bitumen tar**,** to protect these materials from corrosion, while these materials contact with the ground. Now-a-days, the greenhouse construction is of metal type, which is more permanent. For multi-tunnel greenhouses, metallic structures prevail (a predominance of galvanized steel, due to the high cost of aluminium;) or a mixture of materials (wood–wire, steel–wire, steel–wood, steel–concrete) are used over wooden structures. Steel structures (Fig 2), which are normally more expensive than wooden structures, allow for a reduction in the number of interior pillars (relative to wood), easing the interior manoeuvrability (passage of machinery, implementation of thermal screens) and creating fewer shadows than wood, increasing the available light. In addition, steel structures are easier to assemble than wood, have more accessible roof ventilation mechanisms and are more airtight, although the higher heat conduction of metal weakens these advantages. Reinforced concrete structures are not common. RCC is generally limited to foundations and low walls. In permanent bigger greenhouses, floors and benches for growing the crops are made of concrete.

Fig. 2 Polyhouse with steel structure

GLASS

Glass has been traditional glazing material all over the world (Fig 3). Widely used glasses for greenhouse are: (i) Single drawn or float glass and (ii) Hammered and tempered glass. Single drawn or float glass has the uniform thickness of 3 to 4 mm. Hammered and tempered glass has a thickness of 4 mm. Single drawn glass is made in the traditional way by simply pulling the molten glass either by hand or by mechanical equipment. Float glass is made in modern way by allowing the molten glass to float on the molten tin. Coating with metal oxide with a low emissivity is used for saving of energy with adequate light transmittance. Hammered glass is a cast glass with one face (exterior) smooth and the other one (interior) rough. It is designed to enhance light diffusion. This glass is not transparent, but translucent. Tempered glass is the glass, which is quickly cooled after manufacture, adopting a procedure similar to that used for steel. This kind of processing gives higher impact resistance to the glass, which is generally caused by hail. Glass used as a covering material of greenhouses, is expected to be subjected to rather severe wind loading, snow and hail loading conditions. The strength mainly depends on the length/width ratio of the panel and on the thickness of the panel, but the most widely used thickness is 4 mm.

Fig. 3 Glass polyhouse

POLYETHYLENE FILM

Polyethylene is principally used today for two reasons- (i) Plastic film greenhouses with permanent metal frames (Fig 4) cost less than glass greenhouses and (ii) Plastic film greenhouses are popular because the cost of heating them is approximately 40% lower compared to single-layer glass or fiberglass-reinforced plastic greenhouses. The disadvantages are: these covering materials are short lived compared to glass and plastic panels. UV light from the sun causes the plastic to darken, thereby lowering transmission of light, also making it brittle, which leads to its breakage due to wind. A thermal screen is installed inside a glass greenhouse that will lower the heat requirement to approximately that of a double-layer plastic film greenhouse, but this increases the cost of the glass greenhouse. Polyethylene film was developed in the late 1930s in England and spread around the middle of this century. Commonly used plastic for greenhouse coverings are thermoplastics. Basic characteristics of thermoplastics are: (i) thermoplastics consists of long chain molecules, soften with heating and harden with cooling and this process is reversible and (ii) thermoplastics constitute a group of material that are attractive to the designer for two main reasons: (a) Thermoplastics have the following specific physical properties- stiffness, robustness and resilience to resist loads and deformations imposed during normal use and (b) It can readily be processed using efficient mass production techniques, result in low labour charge.

Fig. 4 Polyethylene Polyhouse

Polyvinyl chloride film (PVC films)

PVC films (fig 5) are UV light resistant vinyl films of 0.2 to 0.3 mm and are guaranteed for 4 to 5 years respectively. The cost of 0.3 mm vinyl film is three times that of 0.15 mm polyethylene. Vinyl film is produced in rolls up to 1.27 m wide. Vinyl films tend to hold a static electrical charge, which attracts and holds dust. This in turn reduces light transmittance unless the dust is washed off. Vinyl films are seldom used in the United States. In Japan, 95% of greenhouses are covered with plastic film, out of which 90% are covered with vinyl film.

Fig. 5 PolyVinyl Chloride films

Tefzel T^2 film

The most recent addition of greenhouse film plastic covering is Tefzel T^2 film (ethylene tetrafluoroethylene). Earlier, this film was used as covering on solar collectors. Anticipated life expectancy is 20 years. The light transmission is 95% and is greater than that of any other greenhouse covering material. A double layer has a light transmission of 90% (0.95 x 0.95). Tefzel T^2 film is more transparent to IR radiation than other film plastics. Hence, less heat is trapped inside the greenhouse during hot weather. As a result, less cooling energy is required. Disadvantage is that, the film is available only in 1.27 m wide rolls. This requires clamping rails on the greenhouse for every 1.2 m. If reasonable width strips become available, the price is not a problem, because a double layer covering will still cost less than a polycarbonate panel covering with its aluminum extrusions, and will last longer, and will have much higher light intensity inside the greenhouse.

Fig. 6 ETFE polyhouse