TECHNICAL MANUAL

FOR

IDEal

MICRO IRRIGATION SYSTEMS

IDE
INTERNATIONAL DEVELOPMENT ENTERPRISES

CGIAR Challenge Program on
WATER & FOOD

TABLE OF CONTENTS

1. Introduction

What is Micro Irrigation?
Slow & regular application of water directly to the root zone of plants through a network of economically designed plastic pipes and low discharge emitters.

What are IDEal Micro Irrigation Systems (IMS)?
IDEal Micro Irrigation Systems encompass low-cost drip and sprinklers. IDEal systems are assembled and packaged for small plots along with user-friendly instruction manuals that enable small holders to cultivate commercial crops. In other words, micro irrigation can maximize crop productivity and protect the environment through conserving soil, water and fertilizer resources, while also increasing farmer income.

However, a majority of smallholders in developing countries are deprived of this technology due to its high capital cost and non-adaptability to small land holdings. Until recently, it has been too expensive to be affordable for poor families and too large for tiny plots of land. International Development Enterprises (IDE), a non-profit development organization, has overcome this problem by developing a range of small, easy-to-use, and affordable micro irrigation kits. IDEal Micro Irrigation Systems allow the production of high value crops with less time and money than traditional ways of cultivating and irrigating commercial crops.

IDE has been working on low-cost micro irrigation technology in India and Nepal since 1995. These products are sold as ready-to-use kits, assembled and packaged so that they can be moved off the shelf, installed and used by farmers. An example of one of these technologies is the low-cost IDEal Drip System, consisting of a network of plastic pipes with emitters. The emitters deliver water directly to the root zone in quantities that approach the consumptive use of the plants. Most of the components in a typical low-cost micro irrigation system are manufactured from polyvinyl chloride and various types of polyethylene and polypropylene. The manufacturing technology is based on a simple extrusion or injection molding process. Because of this, manufacturers of plastic pipes can easily adapt the technology to the needs of the smallholders and enable them to cultivate high-value cash crops with small amounts of water to increase their income. With the use of the technology, smallholders are able to increase their income up to two to three times what they make from traditional crops. With available water, farmers can also increase their productive area when using IDEal Micro Irrigation Systems.

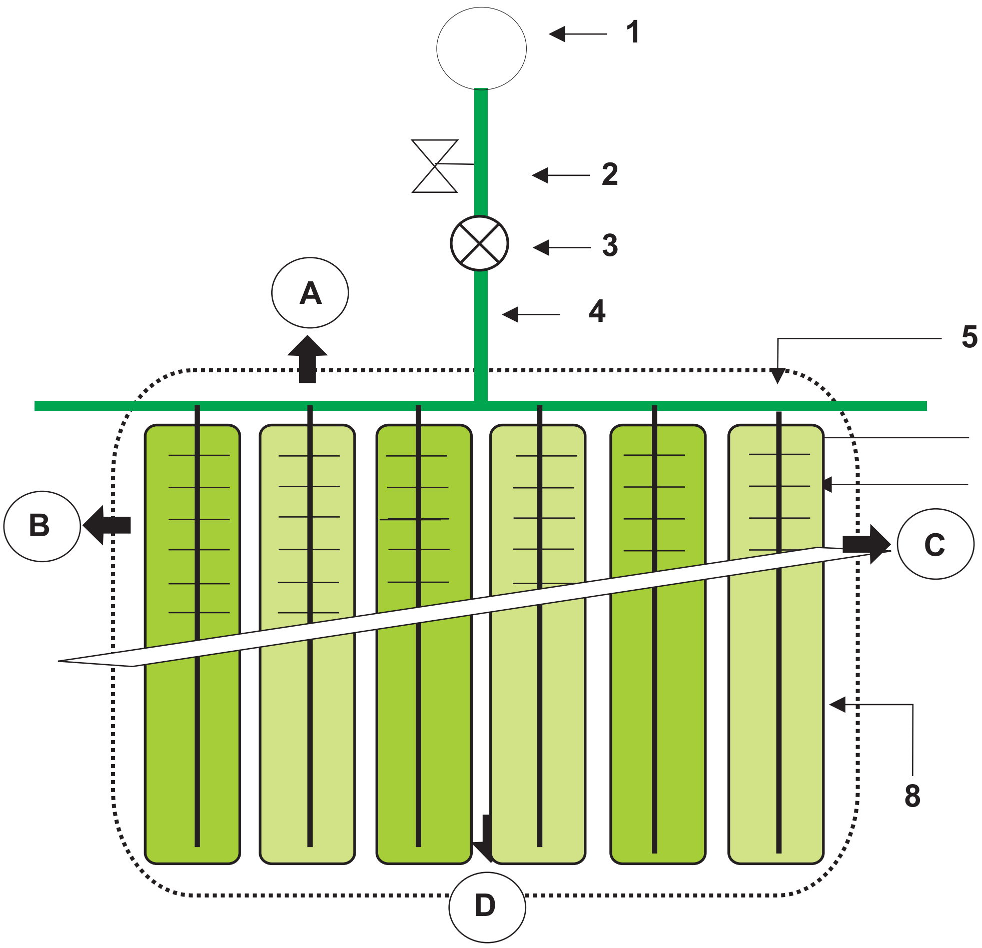
This manual aims at providing skills and knowledge to support an ever-growing network of institutional efforts for the dissemination of IDEal Micro Irrigation Systems. It can also be used for in-group training courses for professional / technical staff of implementing organizations, supply chain participants and the training of farmers on the technology.

2. Advantages of IDEal Micro Irrigation Systems (IMS)

Some of the major advantages of IMS are given below:

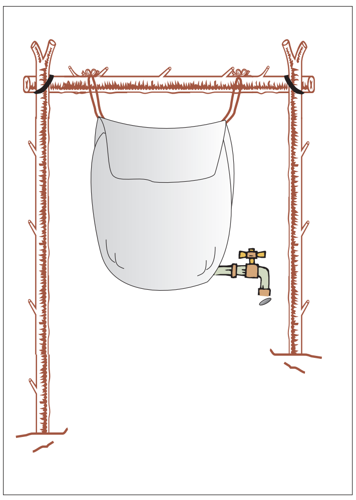
- **Affordability:** IMS is available in affordable sizes from local suppliers at prices lower than other available irrigation systems.
- **Improved Yield:** Slow and regular application of water and nutrients uniformly to all plants improves product quality and uniformity, and increases yield.
- **Water Saving:** Water savings are 50%, compared to traditional irrigation methods. This means that when using IMS, a farmer can irrigate more crop area per unit of water used.
- **Labor Saving:** Less labor is required for irrigation, weeding, and fertilizer application compared to traditional production methods.
- **Fertilizer Saving:** Fertilizer losses are minimized with IMS, reducing fertilizer costs.
- **Energy Saving:** Most of the IMS are gravity operated systems or operated with low horsepower pumps, reducing energy demand for irrigation.
- **Difficult Terrain:** IMS can be used on undulated terrain (hilly areas) where irrigation by traditional methods is difficult.
- **Tolerance to Salinity:** Due to slow and regular application of water by IMS, concentration of salts in the root zone is reduced and by micro-leaching salts are kept away from the root zone.
- **Improved Crop and Disease Control:** Regular irrigation ensures timely inter-culturing operations and spraying, allowing better control over potential crop diseases. It also reduces the incidence of diseases common with flood irrigation.
- **Reduced Cultivation Cost:** Slow and regular application of water keeps an optimum soil-water-air ratio in the soil which is essential for healthy plant growth. It also reduces the need for frequent inter-culturing, weeding, etc. Combined with the above-mentioned savings, cultivation costs on the whole are reduced.
- **Application to Variety of Crops:** A number of different crops can be irrigated using IMS including vegetable crops, fruit crops, commercial cash crops, flowers, etc.

3. Basic Components of IDEal Drip Systems (IDS)



No.	Notation
1.	Water Source
2.	Control Valve
3.	Filter
4.	Main Pipe
5.	Sub-Main Pipe
6.	Lateral Pipe
7.	Micro-tube / Emitter Baffle / Dripper
8.	Vegetable bed

ABCD-Area for Expansion



1. Water Source: The IDEal Drip System is a low-pressure system that uses gravity to increase water pressure. The water source can be an overhead tank placed at a minimum of one meter above ground level for smaller systems up to 400 m^2 area. For larger systems, the height of the tank should be increased. If the height of the tank is not increased, the system can be connected to a pump that lifts water from sources such as a well, farm pond, storage tank, or a stream / canal. A manually operated pressure pump also can be used to lift water from a shallow water table (up to 7 meters) and used for the system.

2. Control Valve: A valve made of plastic or metal to regulate required pressure and flow of water into the system. There are valves of various sizes depending on the flow rate of water in the system.

3. Filter: The filter ensures that clean water enters the system. There are different types of filters - screen, media and disc. Different sizes of filters are available depending on the flow rate of water in the system.

4. Mainline: Pipe made of poly vinyl chloride (PVC) or polyethylene (PE) to convey water from the source to the sub-main line. PE pipe material is normally made from high-density polyethylene (HDPE), low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE). The size of pipe depends on the flow rate of water in the system.

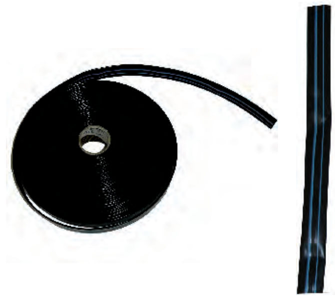
5. Sub-main: Made of PVC / HDPE / LDPE / LLDPE pipe to supply water to the lateral pipes. Lateral pipes are connected to the sub-main pipe at regular intervals. The size of pipe depends on the flow rate of water in the system.

6. Lateral: Pipes made of LLDPE or LDPE placed along the rows of the crop on which emitters are connected to provide water to the plants directly. The lateral pipe size is from 12 mm to 16 mm in most IDEal Drip Systems.

7. Emitters: A device through which water is emitted at the root zone of the plant with required discharge. Different types of emitters used in IDEal Drip Irrigation Systems are described below:

i) **Micro-tube:** Straight or curled LLDPE tube with an inner diameter ranging from 1 to 1.2 mm. The discharge from the micro-tube is directly proportional to the operating pressure and inversely proportional to its length. The operating pressure that is required can be as low as 1-5 meters.

ii) **Drip Tape / Built-in Dripper:** It has built-in drippers / outlets on the lateral line which give a continuous wetting strip. It is mainly used for row crops. The operating pressure required is from 1-5 meters.



8. Fittings & Accessories: Various fittings required in IDS are described below.

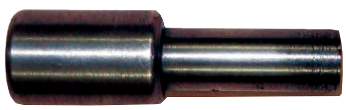
i) Tee Connector: Tee Connector: Tee connectors of various sizes are required in IDEal Drip Systems to connect a branch to the main pipe, the main pipe to sub-main pipes, the lateral pipes to sub-main pipes, etc. The tee connectors can be either the equal tee or reducing tee type including 12mm x 12mm, 16mm x 12mm, 16mm x 16mm, 25mm x 12mm, and 32mm x 12 mm.

ii) Straight Connector: The straight connector is also called a joiner and is required to connect pipes. It can be either the equal joiner or reducing joiner including 12mm x 12mm, 12mm x 16mm, 25mm x 32mm, 32mm x 40 mm, and

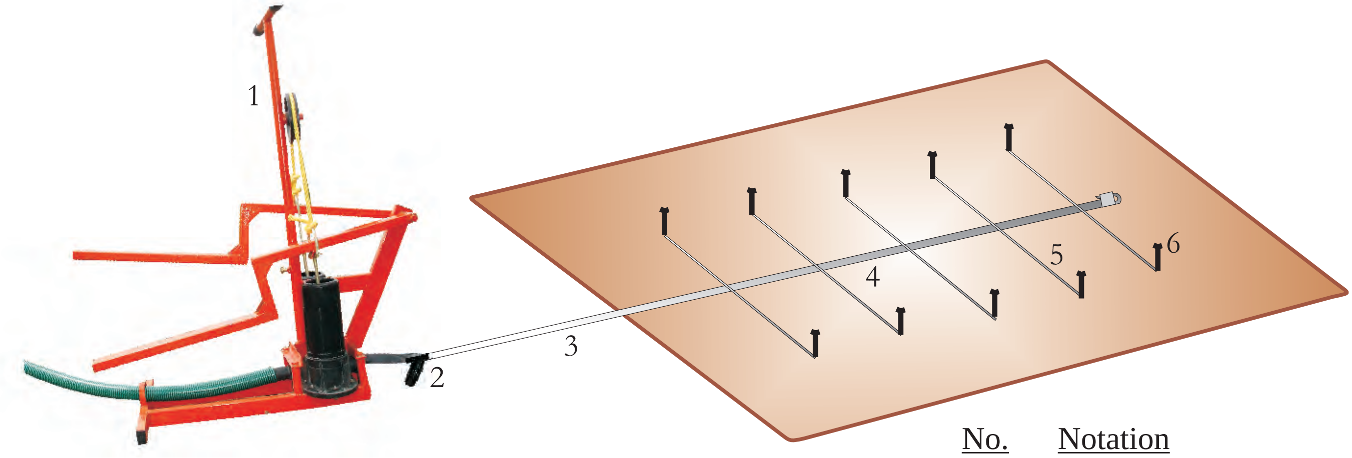
iii) **Take-Off Tee:** It is used to connect the lateral pipes to the sub-main pipe in larger systems. It is fixed in the wall of sub-main pipe with the help of a rubber washer called a gromate. It is available for different sizes of lateral pipes including 12mm and 16mm.

iv) Wooden Guide: It is used to protect the bottom of the sub-main pipe while the metal punch is used to punch a hole in the sub-main pipe from the top.

v) Metal Punch: It is used along with the wooden guide to punch a hole on the top of the sub-main pipe in order to connect the take-off tee to the sub-main pipe.



4. Basic Components of IDEal Sprinkler Systems (ISS)



No.	Notation
1.	Water Source / Pump
2.	Filter
3.	Main Pipe
4.	Sub-Main Pipe
5.	Lateral Pipe
6.	Mini Sprinkler

1. Water Source / Pump: The IDEal Sprinkler System uses a pump or gravity pressure to operate the sprinklers. The water source can be an overhead tank placed at a minimum of 5-10 meters above ground level, a spring running downhill, or a well with a pump.

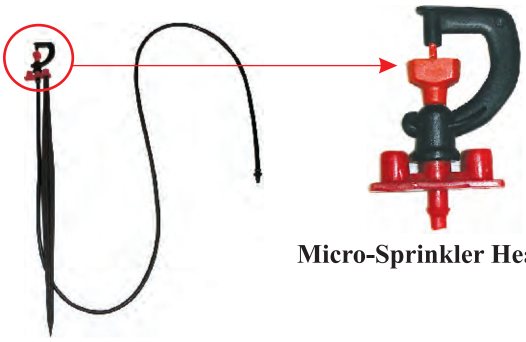
2. Filter: The filter ensures that clean water enters the system. There are different types of filters - screen, media and disc. Different sizes of filters are also available, and the appropriate size depends on the flow rate of water in the system. Both micro sprinkler heads and mini sprinkler heads have small nozzles, so they require filtered water in order not to clog. On the other hand, an impact sprinkler head has a larger nozzle and if the water is relatively clean, a filter may not be required.

3. Mainline: Pipe made of PVC or PE to convey water from the source to the sub-main line. PE pipe material is normally made from HDPE, LDPE, and LLDPE. The size of pipe required depends on the flow rate of water in the system.

4. Sub-main: Made of PVC / HDPE / LDPE / LLDPE pipe to supply water to the lateral pipes. Lateral pipes are connected to the sub-main pipe at regular intervals. The size of pipe depends on the flow rate of water in the system.

5. Lateral: Pipes made of LLDPE or LDPE placed along the rows of the crop on which emitters are connected to provide water to the plants directly. The lateral pipe size is from 16 mm to 32 mm in most IDEal Sprinkler Systems.

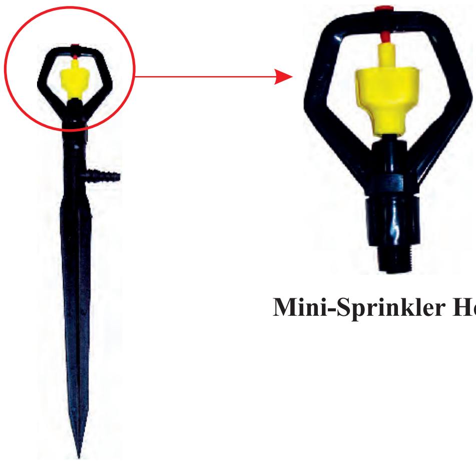
6. Sprinkler Head: A device through which water is emitted near the plant. There are three types of sprinklers as given below:



Micro-Sprinkler Head

i) **Micro-Sprinkler:** It has a small rotating device to spray water as light precipitation. It covers an area with radius of 3-4 meters. Operating pressure required is 5-10 meters.

ii) **Mini Sprinkler:** It has a small rotating device to spray water as light precipitation. It covers an area with a radius of 6-8 meters. The operating pressure required is 5-15 meters.



Mini-Sprinkler Head

iii) **Impact Sprinkler:** It is made of metal or plastic and has a spring which makes the hammer move, rotating the sprinkler. It covers an area with a radius of 10-12 meters and operating pressure required is 10-20 meters.

7. Fittings & Accessories: Various fittings required in IDEal sprinkler system are described below.

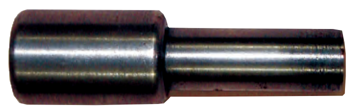
i) Tee Connector: Tee connectors of various sizes are required in ISS to connect a branch to the main pipe, the main pipe to sub-main pipes, the lateral pipes to sub-main pipes, etc. The tee connectors can be either the equal tee or reducing tee type including 12mm x 12mm, 16mm x 12mm, 16mm x 16mm, 25mm x 12mm, and 32mm x 12 mm.

ii) Straight Connector: The straight connector is also called a joiner and is required to connect pipes. It can be either the equal joiner or reducing joiner including 12mm x 12mm, 12mm x 16mm, 25mm x 32mm, 32mm x 40 mm, and 40mm x 50mm.

iii) Take-Off Tee: It is used to connect the lateral pipes to the sub-main pipe in larger systems. It is fixed in the wall of sub-main pipe with the help of a rubber washer called a gromate. It is available for different sizes of lateral pipes including 12mm and 16mm.

iv) Wooden Guide: It is used to protect the bottom of the sub-main pipe while the metal punch is used to punch a hole in the sub-main pipe from the top.

v) Metal Punch: It is used along with the wooden guide to punch a hole on the top of the sub-main pipe in order to connect the take-off tee to the sub-main pipe.



vi) Stakes/Tripod stand: Micro sprinklers and mini sprinklers are mounted on 12-inch or 18inch long plastic stakes and connected to the lateral pipes through an extension pipe. Impact sprinklers are mounted on a metal tripod stand.

5. IDEal Micro Irrigation System Models

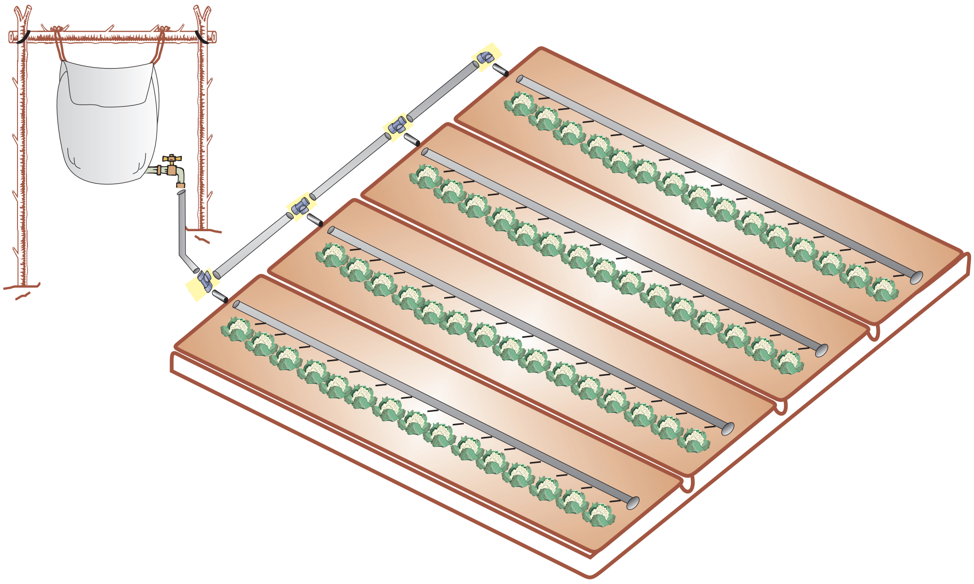
Standard packaged kits were developed based on different irrigation areas, number of plants and type of crops of interest to smallholder farmers. These kits can be upgraded or combined to form larger systems by using additional fittings and accessories. The three main kit types are drip kit with microtube as emitter, drip kit with built-in dripper, and shiftable sprinkler kit.

5.1 IDEal Drip Systems

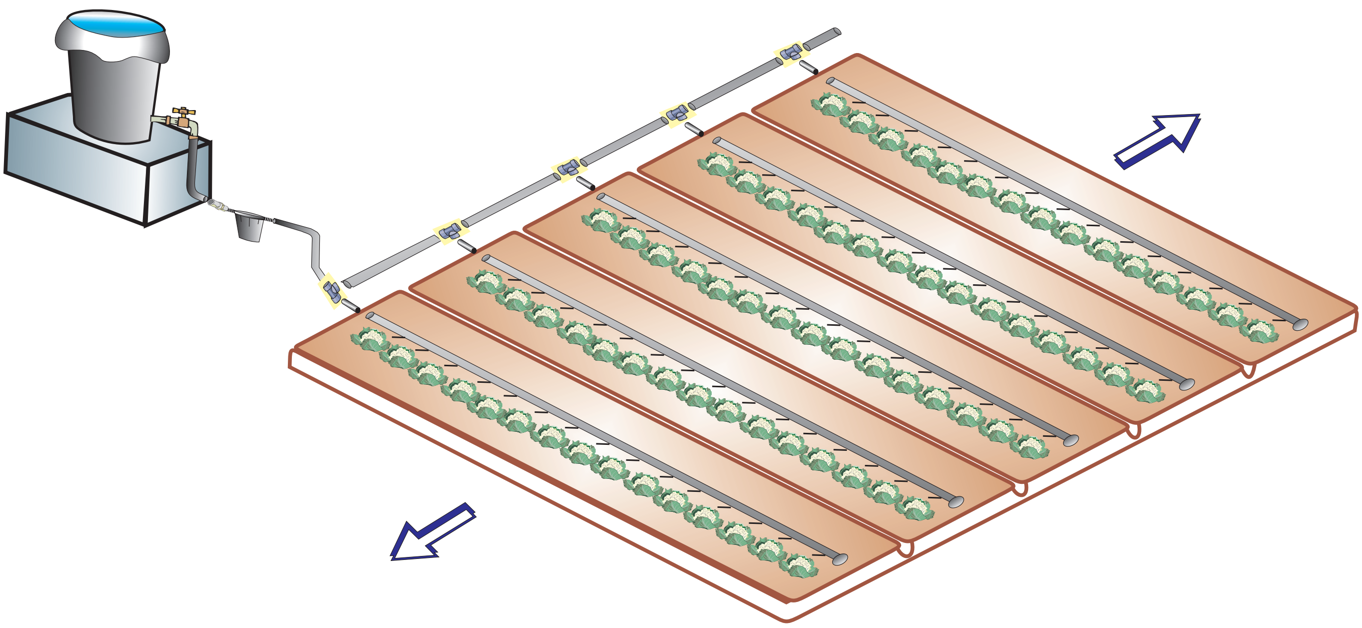
Table 5.1.1 IDEal Drip System Models and Specifications

Specification	IDS20 (Family Nutrition Kit)	IDS100 (Vegetable Garden Kit)	IDS500 (IDEal Drip Kit 500 m^2)	IDS1000 (IDEal Drip Kit 1000 m^2)
Area Coverage	20 m^2	100 m^2	500 m^2	1000 m^2
Type of Emitter	Micro-tube 1.2 mm I.D., 25 cm long	Micro-tube 1.2 mm I.D., 25 cm long	Micro-tube 1.2 mm I.D. 25 cm long	Micro-tube 1.2 mm I.D., 25 cm long
No. of Emitters / Micro-tubes	50	300	1500	3000
Emitter / Micro-tube Spacing	40 cm	30 cm	30 cm	30 cm
Type of Lateral	LLDPE 16 mm O.D.	LLDPE 16 mm O.D.	LLDPE 16 mm O.D.	LLDPE 16 mm O.D.
Lateral Length	5.0 m	10 m	12 m on each side	16 m on each side of the sub-main
No. of Laterals	4	10	20	60
Lateral Spacing	1 m	1 m	1 m	1 m
Type of Sub-Main	LLDPE 16 mm O.D.	LLDPE 16 mm O.D.	LLDPE 48 mm O.D.	LLDPE 48 mm O.D.
Sub-main Length	4 m	10 m	25 m	35 m
Filter	Screen Filter (16 mm inlet & outlet size)	Screen Filter (16 mm inlet & outlet size)	Screen Filter (32 mm inlet & outlet size)	Screen Filter (32 mm inlet & outlet size)
Operating Head / Height of Tank	1 meter	1 meter	1.5 meter	1.5 meter
Emitter Flow (microtube as emitter)	3.2 lph	2.8 lph	2.4 lph	2.2 lph
Emitter Flow (built-in dripper)	4.0 lph / meter	4.0 lph / meter	4.0 lph/meter	4.0 lph / meter
Water Storage	20 liters	200 liters	1000 liters	2000 liters
Crops	Vegetable crops such as tomato, eggplant, onion, cabbage, rapeseed, paprika, cauliflower, garlic, watermelon, cucumber, lettuce, etc.		Vegetable crops such as tomato, eggplant, onion, cabbage, rape seed, paprika, cauliflower, garlic, watermelon, cucumber, lettuce, etc. Fruit crops such as banana, papaya, pomegranate, citrus, mango, etc., with required modifications.	
Note: The spacing given above for emitters and lateral pipes is recommended spacing for many vegetable crops. Different spacing of emitters and lateral pipes can be used based on plant and row spacing of fruit and vegetable crops grown in particular region.				

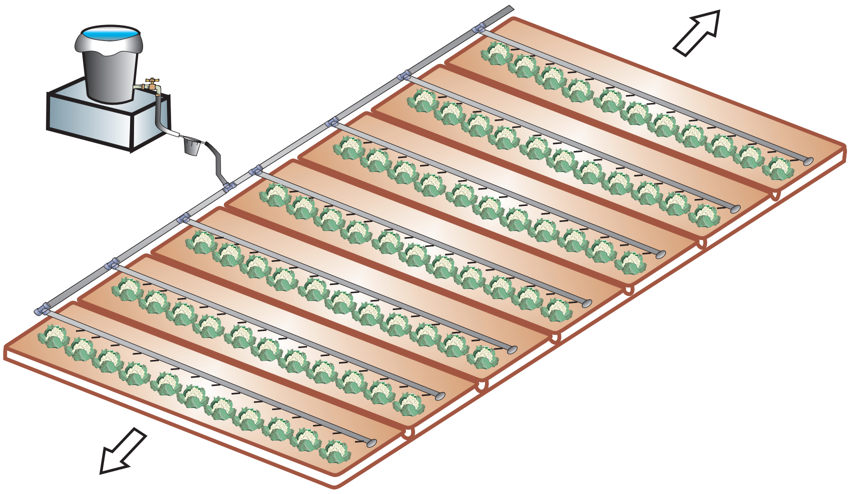
5.1.1 Family Nutrition Kit 20 m^2 - IDS 20



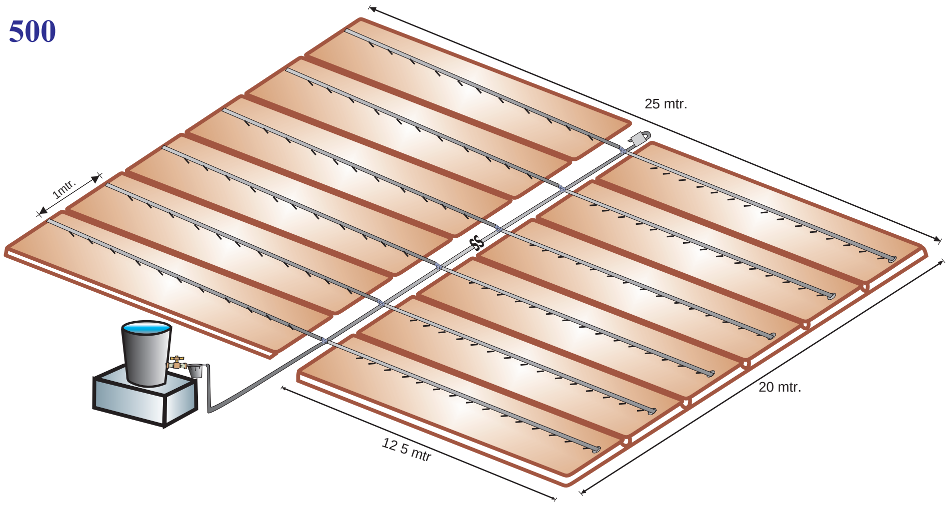
5.1.2 Vegetable Garden Kit 100 m^2 - IDS 100



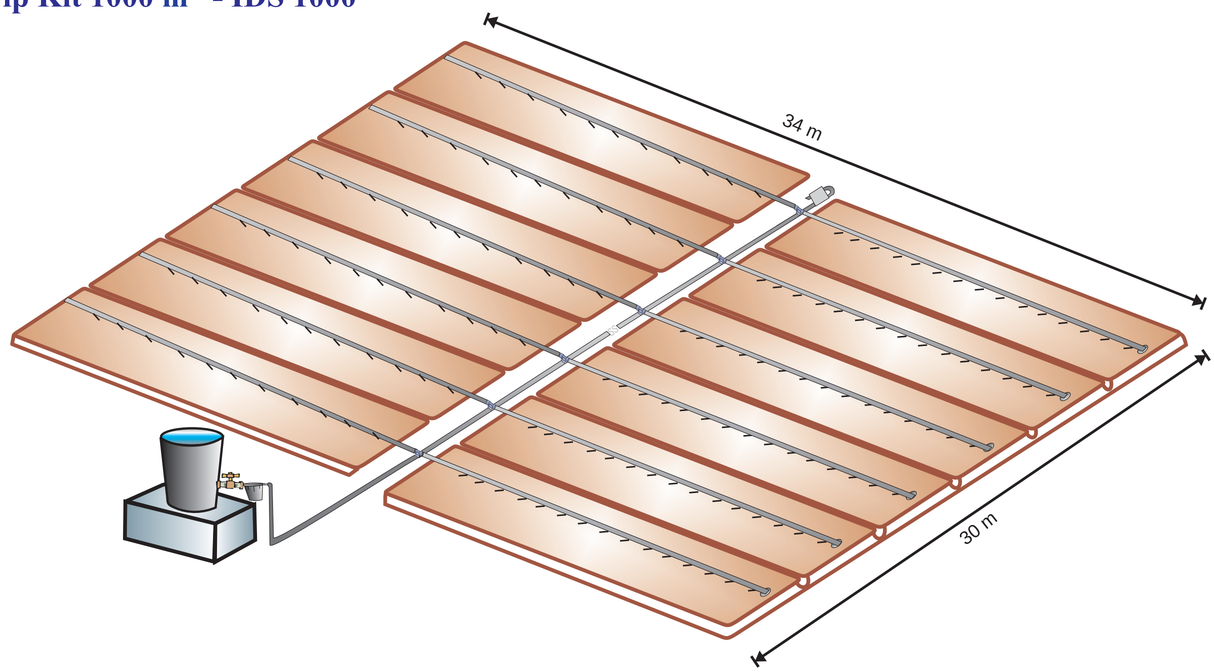
5.1.3 IDEal Drip Kit 200 m^2 - IDS 200



5.1.4 IDEal Drip Kit 500 m^2 - IDS 500



5.1.5 IDEal Drip Kit 1000 m^2 - IDS 1000

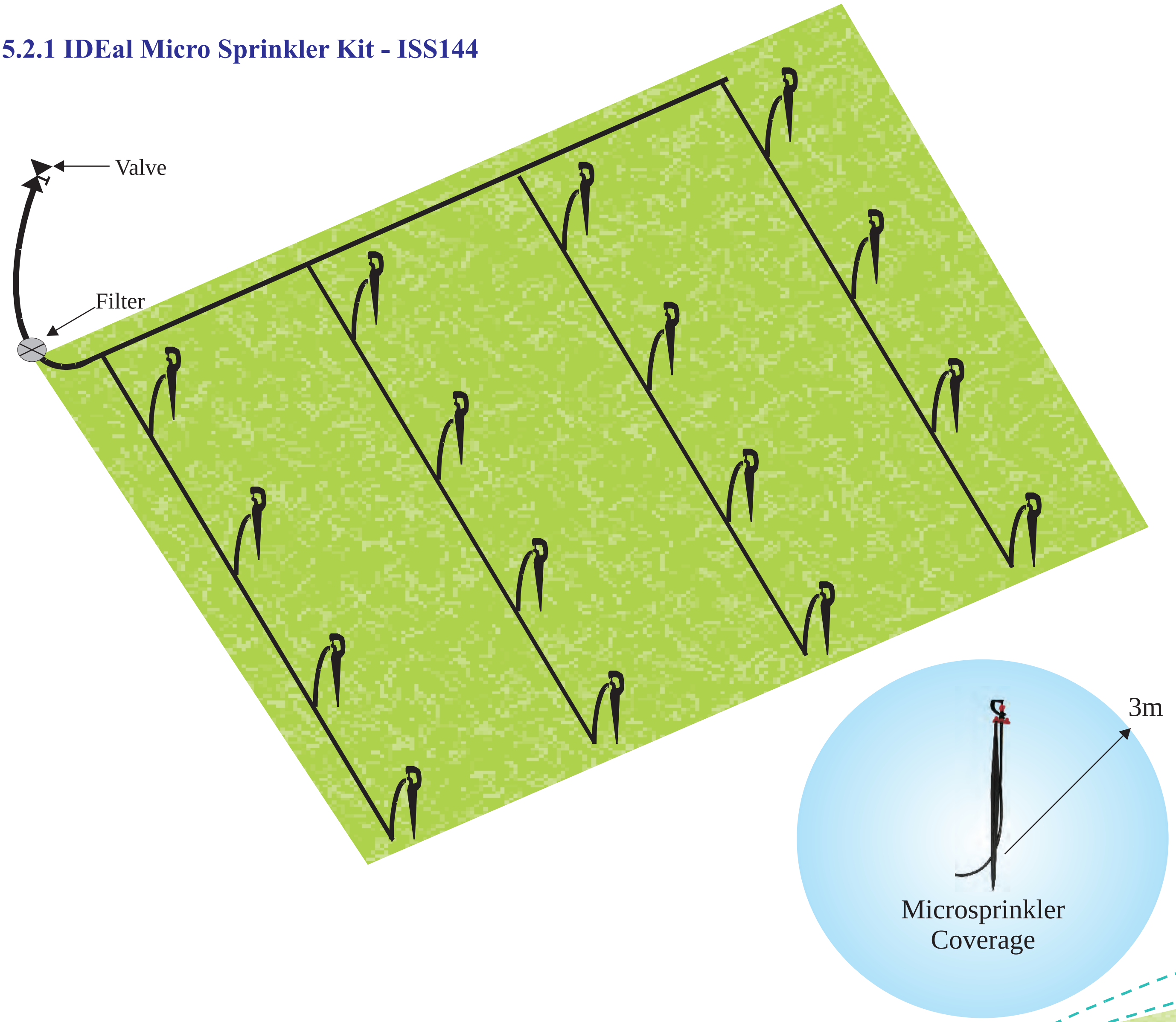


5.2 IDEal Sprinkler Systems

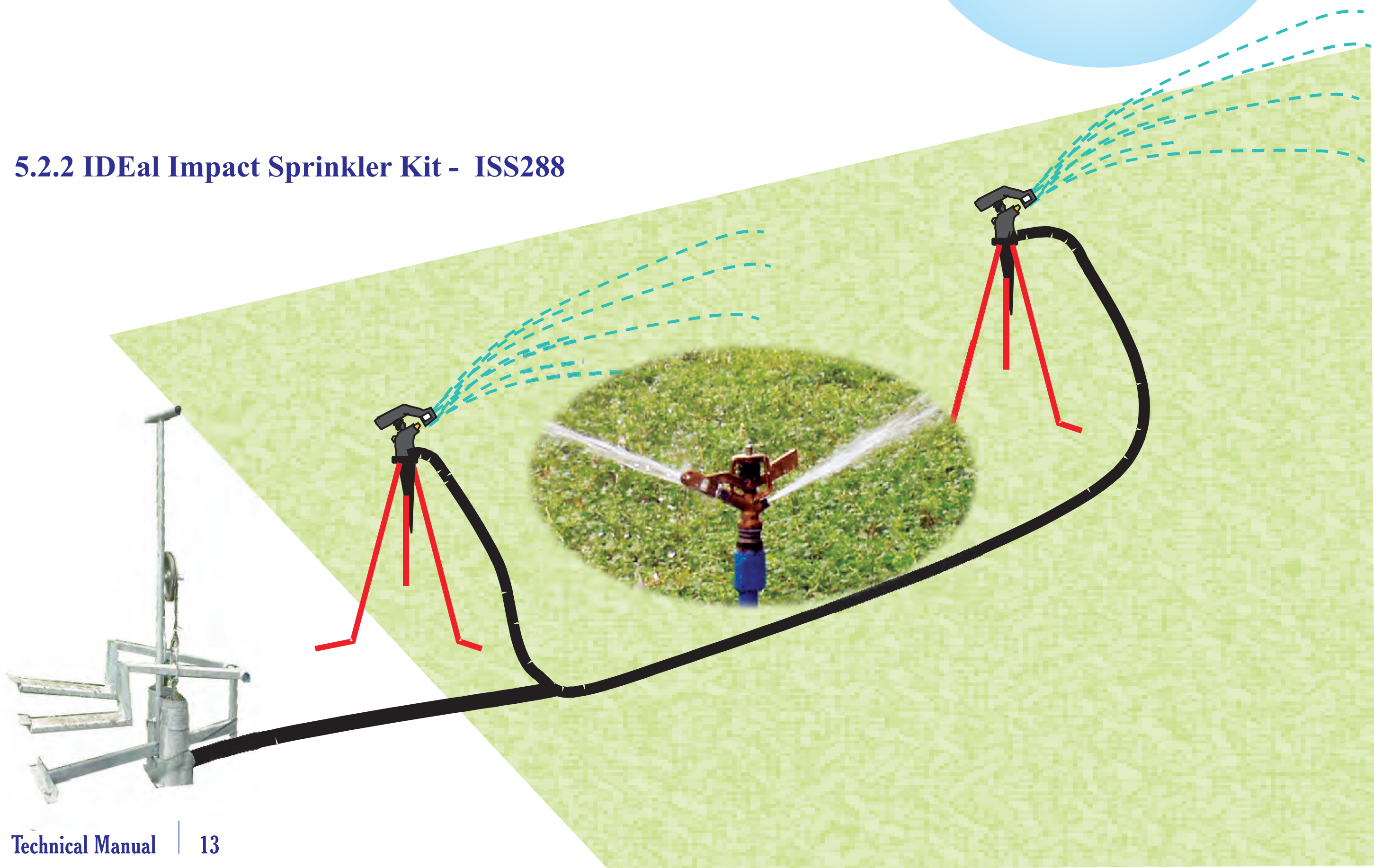
Table 5.2.1 IDEal Sprinkler Systems Models and Specifications

Specification	ISS144 (Microsprinkler Kit)	ISS288 (Impact Sprinkler Kit)	ISS360 (Mini Sprinkler Kit)	ISS576 (Mini Sprinkler Kit)
Area Coverage	144 m^2 with no shift (one use)	288 m^2 With no shift (one use)	360 m^2 With no shift (one use)	576 m^2 With no shift (one use)
Type of Emitter	Micro Sprinkler	Sprinkler	Mini Sprinkler	Mini Sprinkler
No. of Emitters / Sprinklers	16	2	10	16
Emitter Spacing	3 m	12 m	6 m	6 m
Type of Lateral	LLDPE 16mm O.D.	LLDPE 32 mm O.D.	LLDPE 16 mm O.D.	LLDPE 16 mm O.D.
Lateral Length	13 m	24 m	3 m on one side of the submain	9 m on one side of the submain
No. of Laterals	4	1	10	8
Lateral Spacing	3	-	6 m	6 m
Sub-Main Size	LLDPE 16mm O.D.	-	LLDPE 48 mm O.D.	LLDPE 48 mm O.D.
Sub-main Length	12	-	30 m	25 m
Filter	Screen Filter 16 mm size	-	Screen Filter 32 mm size	Screen Filter 32 mm size
Operating Head	5 m 10 m	10 m 15 m	10 m 15 m	10 m - 15 m
Emitter Flow	30 40 lph	900-1200 lph	200 300 lph	200 300 lph
Type of crops	Vegetables, Flowers and other closely spaced crops like Onion and Garlic.			

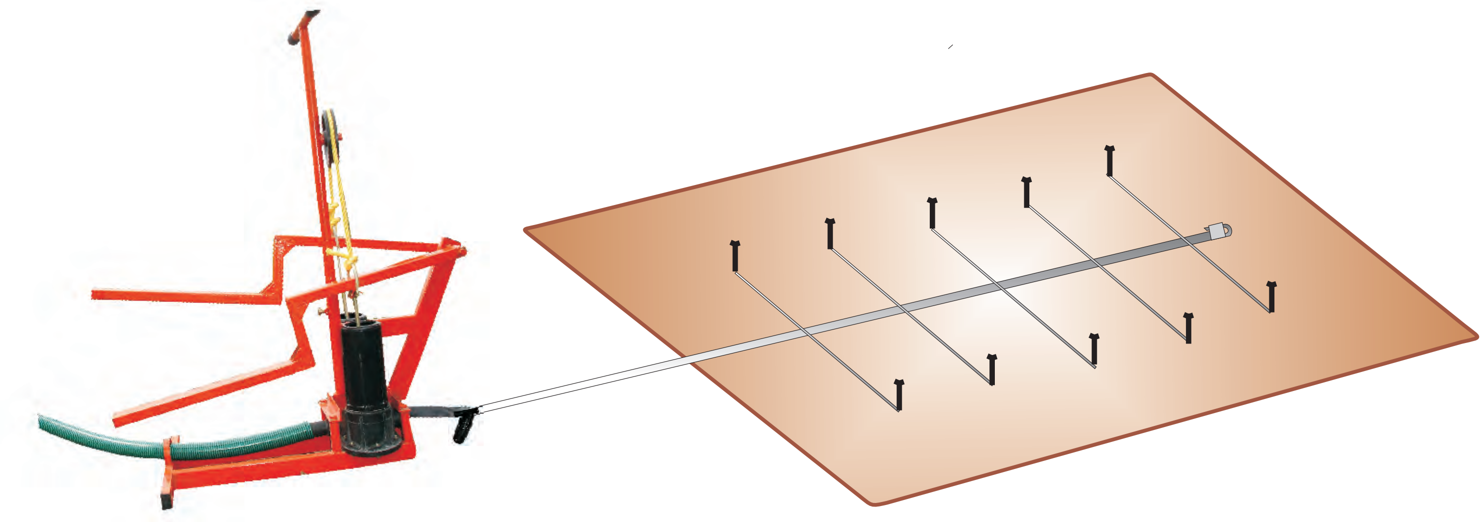
5.2.1 IDEal Micro Sprinkler Kit - ISS144



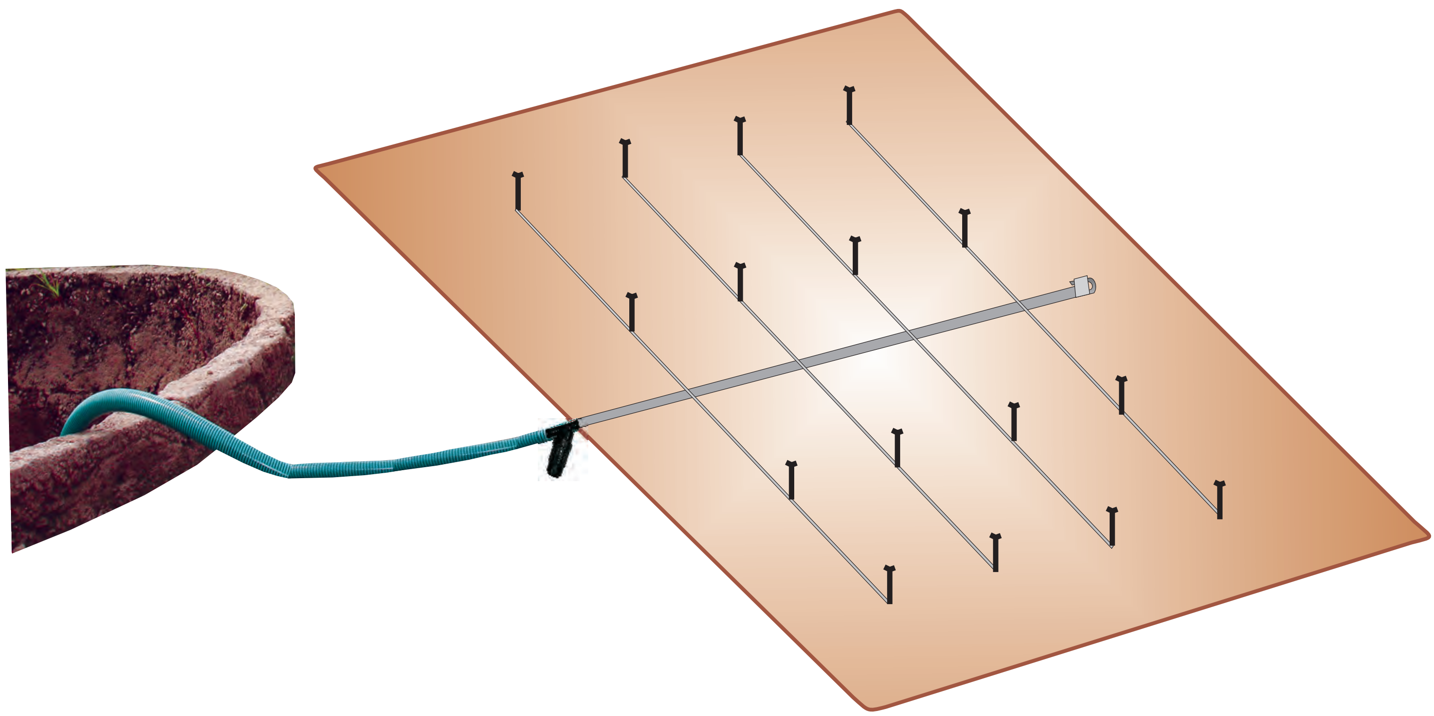
5.2.2 IDEal Impact Sprinkler Kit - ISS288



5.2.3 IDEal Mini Sprinkler Kit - ISS360



5.2.4 IDEal Mini Sprinkler Kit - ISS576



6. Customization of IDEal Drip Irrigation System

IDEal Drip System Kits have standard sizes and are have a base design for small plots with fixed dimensions. However, farmers often have plots of varied size and dimensions. Therefore, IDEal Drip System Kits can be customized for a particular plot or adjusted to increase or reduce the in-row spacing or between-row spacing according to the farmer's need. It can be done in following ways:

1. Adjusting the length of the lateral pipes
2. Connecting additional kits to the same water source
3. Designing a customized system using simple rules

6.1 Adjusting length of the lateral pipe:

Using an IDEal Drip System Kit for a smaller area than the specified size can be done easily by closing the emitters or reducing lateral / sub-main length by using an end cap. To use the kit for a larger area, increase the lateral line length or connect additional lateral lines to the sub-main pipe. Make sure to increase the pressure head (height of water tank) to provide enough pressure for the increased lines. To increase the pressure and ensure water distribution uniformity, follow the guidelines of the table below. The table gives the maximum length the lateral lines can be with certain pressures for each kit. Water storage or frequency of storage tank filling will also need to be increased to account for the additional water required with increased area.

Table 6.1.1: Appropriate length of lateral lines according to pressure

Type of Kit	Length of 16mm Lateral at Different Pressure Heads (Tank Height)				
	1 m Head	1.2 m Head	1.4 m Head	1.6 m Head	1.8 m Head
IDS20	20	23	27	31	35
IDS100	19	22	27	30	35
IDS500	19	21	26	29	34
IDS1000	19	20	26	29	33

6.2 Connecting additional kits to the same water source

Instead of changing the lateral lines, a larger area can be irrigated by combining kits. Up to four kits can be easily combined with a single water source, provided the source has enough capacity to provide adequate water for all of the kits. The following table shows the additional area that can be obtained by adding kits.

Table 6.2.1: Total irrigation area when combining multiple kits

Type of Kit	Area with one kit (m^2)	Area with two kits (m^2)	Area with three kits (m^2)	Area with four kits (m^2)
IDS20	20	40	60	80
IDS100	100	200	300	400
IDS500	500	1000	1500	2000
IDS1000	1000	2000	3000	4000

6.3 Designing a customized system using simple rules:

6.3.1 Design Inputs:

IDEal Drip System kits are designed to provide high irrigation efficiency and uniform distribution of water and nutrients for high value crops as compared to conventional flood irrigation systems. If a larger system is required by the farmer, it can be designed within the allowable discharge variation limit by using the following procedure. The inputs required to make an effective customized drip micro irrigation system are as follows:

1. Layout of the area
2. Details of the water source and soil type
3. Agronomic details (plant spacing, crop period, season, canopy, etc.)
4. Climatic data (rainfall, temperature, evapo-transpiration, etc.)

By using this information, a complete drip micro irrigation system can be designed which will give the following outputs.

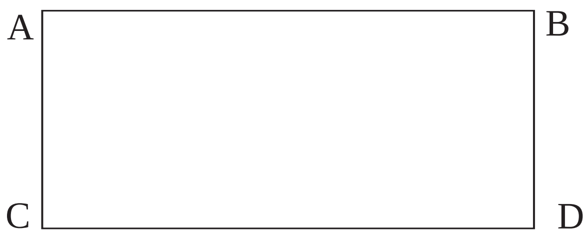
6.3.2 Design Outputs:

1. Detail layout of the system in the field
2. Emitter selection and placement
3. Size and length of mainline, sub-main and lateral pipes
4. Pumping and filtration requirement
5. Operating schedule for irrigation.
6. Material and cost estimate

System design starts with selection of the suitable emitter depending on type of crop, water requirement, operating time, soil type, and water quality. The length and size of lateral lines are determined based on the lateral line flow rate, field size, etc as shown in Table 6.3.7. Similarly, the size and length of the sub-main pipe is determined. Each sub-main is an individual unit with its own control valve. The whole area is then divided into different sub-main units and the number of sub-main units that can operate at any one time is based on the existing pumping / water source capacity. Sections should be designed such that the discharge is similar for all the sections. To determine the appropriate length of the sub-main pipe, reference Tables 6.3.8A and 6.3.8B. The mainline is then planned connecting all the sub-mains by taking the shortest possible route. The length of the main pipe can be determined based on the flow rate so that frictional head loss is within specified limits and total pressure head required for the system is within pump / water source capacity. Reference Table 6.3.9 to find the appropriate length for the main pipe. If there is no pump, then the pump requirement is worked out from total discharge and pressure head required for the system. Depending on the flow rate and water quality, a suitable filtration device is selected. The total quantity of all the components is calculated from the layout to prepare a cost estimate.

6.3.3 Survey:

The following survey inputs are required to prepare an accurate layout of any area (size, shape and slope) for design of micro irrigation system:



1. Straight distance between points at the corners (e.g. AB, BC, CD & DA). It can be measured with a tape in a straight line with corner points duly identified by setting down stones or sticks.

2. Angle at the corner: For a three-cornered area, distances of three of the sides is sufficient to make the layout. For a four-cornered area, any one angle has to be measured along with distances of all sides. For a five-cornered figure, two consecutive angles are required and so on for multiple sides. A distance of 10 meters is marked from the corner on each line, forming the angle, and then a tie length is measured between these points. To determine the corner angle, use the following equation.

   Tan (angle) = Length of opposite side / Length of adjacent side

3. Elevation: Slope of the ground surface may be judged with the naked eye for small plots wherever possible and taken into consideration while designing the drip system. If the ground surface is too undulating and the slope is difficult to judge, levels should be taken with a leveling instrument and contours drawn on the map to make a proper design of the drip system.

4. Water Source: Position of water source (tank, well, reservoir, pond, river, stream, existing pump, pipeline, etc.) should be marked on the map and the following details noted.
   a) Size, volume, flow rate, and height above ground level or depth from ground surface or water source.
   b) Pump details for the existing pump including suction, delivery, actual discharge & head, operating time, pump HP, expected discharge & head.
   c) Quality of water, impurities in water (algae, sand /silt, etc.) If a water analysis report is available, it should be enclosed with the survey report or if possible the farmer should try to have it analyzed at a local laboratory.

5. Agro-climatic details: The details of existing or future cropsshould be noted including specific areas, crop spacing (plant to plant distance x row to row distance), number of plants and number of rows, crop duration, expected canopy, rainfall, evapo-transpiration, etc.

6. Soil details: The details of soil quality visible to the naked eye should be noted including heavy soil or light soil depending on soil texture (proportion of clay, silt & sand.) If a soil analysis report is available it should be enclosed with the survey report or the farmer should try to have it analyzed at a local laboratory.

7. Permanent details of the land: Location of farm house, large trees, rocks, etc. should be marked by taking angular measurements from a minimum of two points so that they can be plotted accurately on the survey plan.

Survey Plan: From the above information, a plan of the area surveyed can be prepared on a 1:1000 scale. For smaller areas, an appropriate scale can be used depending on the size of the area. The drip system layout can be prepared on this plan and then it can be used for installation.

6.3.4 Water Requirement

The water requirement of plants depends on many factors viz. temperature, humidity, soil type, wind velocity, growth stage, shade / sun, etc. Plants absorb soil moisture and transpire it to the atmosphere during the process of photosynthesis. Some amount of water is retained in the plant tissue and the rest of the soil moisture gets evaporated to the atmosphere. Drip irrigation involves frequent application of water, even on a daily basis. Therefore, water requirement of the plant per day is equivalent to the rate of potential evapo-transpiration per day. Evapo-transpiration is the quantity of water transpired by the plants plus the quantity of water retained in the plant tissue and water evaporated from the soil surface. The reference values for evapo-transpiration are normally available for a particular area at the nearest meteorological observatory.

Water requirement can be calculated as:

WR (Liters per day) = ET x Kc x Cp x Area, where
ET is evapo-transpiration (mm per day)
Kc is crop factor
Cp is canopy factor
Area in sq. meter

If specific crop factor values are not available, then it can be assumed as one.
The canopy factor is the percentage of area covered by plant canopy (foliage). It varies according to the growth stage of the plant.

The area for orchards is the multiplication of the distance from plant to plant (m) and distance from row to row (m). For row plantation, the unit area can be taken to calculate water requirement.

Example: Calculate peak water requirement for grapes planted at the spacing of 2 m by 2m. Assume peak ET for the area as 6 mm per day, crop factor for grape 0.8 and canopy factor 0.8.

Peak water requirement per day = 6 x 0.8 x 0.8 x 2 x 2
= 15.4 liters per day per plant

It is called peak water requirement because it is calculated on the basis of the highest rate of evapo-transpiration which normally occurs in the high temperatures and windy conditions of summer. However, daily water requirements will depend on the daily rate of evapo-transpiration which is less during winter and higher in summer.

The drip system has constant discharge at the given pressure. Therefore, operating time can be varied to provide the required amount of water depending on the season.

6.3.5 Operating Time / Irrigation Schedule

Operating (irrigation) time is the duration of irrigation system operation that provides the required amount of water for the plants. It can be calculated as follows:

$$\text{Irrigation time (hrs / day)} = \frac{\text{Water requirement (liters per day)}}{\text{Application rate (liters per hour)}}$$

Example 1

Calculate irrigation time for a papaya tree with daily water requirement of 10 liters per day per plant and provided the microtube system with a discharge rate of 4 liters per hour.

$$\text{Irrigation time (hrs / day)} = \frac{10}{4} = 2.5 \text{ hrs / day}$$

Example 2

Calculate the irrigation time required for a 100 sq. meter vegetable plot with a daily water requirement of 400 liters and a microtube system discharge rate of 200 liters per hour.

$$\text{Irrigation time (hrs / day)} = \frac{400}{200} = 2 \text{ hrs / day}$$

6.3.6 Selection of Emitter

The emitter is the most important part of a drip system because it delivers water at the desired rate to the plant and maintains water application uniformity over the entire irrigated area. An emitter should match particular field conditions including type of crop, spacing of the plants, terrain, water requirement, water quality, operating time, pressure head, etc. Some of the criteria that can be applied to the selection of dripper are given below:

1. Reliability against clogging and malfunctioning
2. Emission uniformity
3. Simple to install and maintain
4. Pressure compensation in case of undulated terrain
5. Percentage area wetted
6. Flow rate
7. Operating pressure
8. Cost

Table 6.3.6.A: Types and application of major type of emitters to different crops

Type of Emitter	Flow Rate (LPH)	Operating Pressure (m)	Application to type of crop and terrain
Micro-tube, Online dripper, Inline drippers.	1-10	1-10	Vegetable and fruit crops on flat terrain
Self or Pressure compensating dripper	1-10	10-30	Vegetable and fruit crops on uneven land
Line source tube / Thin walled Tape	1-5	1-15	Long row crops
Micro Sprinkler / Micro Jet	20-100	5-50	Vegetable and nursery crops
Mini Sprinkler	500-1000	10-20	Closely spaced crops

Table 6.3.6.B: Flow rate for different lengths of microtube at different pressure head

Pressure	Length of Microtube (m)							
Head (m)	0.20	0.25	0.30	0.45	0.60	0.90	1.20	1.50
0.50	3.23	2.83	2.54	1.99	1.67	1.31	1.10	0.97
1.00	5.25	4.59	4.12	3.23	2.72	2.13	1.79	1.57
1.50	6.98	6.10	5.47	4.29	3.61	2.83	2.38	2.08
2.00	8.53	7.46	6.69	5.25	4.41	3.46	2.91	2.55
2.50	9.98	8.73	7.82	6.13	5.16	4.05	3.40	2.98
3.00	11.33	9.91	8.89	6.97	5.86	4.60	3.87	3.38
4.00	13.86	12.13	10.87	8.52	7.17	5.62	4.73	4.14

6.3.7 Design of Lateral

In most of the drip systems LLDPE laterals of 12 mm to 16 mm size are used. An important point to consider while designing the lateral pipe is the slope of the field. If the average slope of the field is less than 3% in the direction of the lateral, laterals can lie along the slope. However, if the slope of the field is more than 3%, laterals should be used along the contours. Additionally, friction loss along the laterals must stay within the allowable limit. This limits the length laterals can be along each side of the sub-main line. The desirable limit for emitter flow variation is less than 10%, but depending on the crop, variation of 10 to 20% is acceptable. For 10% variation in discharge, approximately 20% variation in the available head is acceptable. Taking into consideration all of these limitations, the maximum allowable length of laterals can be calculated from flow equations like the Hazen-Williams equation (using C 150):

$$H_l = \frac{5.35\, Q^{1.852}\, L}{D^{4.871}}$$

where H_l is pressure loss due to friction (m);
Q is total discharge of lateral (lps);
L is length of lateral (m);
and D is inside diameter (cm).

To cover the range of emitter discharge and spacing, a parameter called Specific Discharge Rate (SDR) is used. It is actually flow per unit length of the lateral. It can be calculated as given below.

$$\text{Lateral SDR (lph/m)} = \frac{\text{Emitter flow rate (lph)}}{\text{Spacing between two emitters (m)}} = \frac{\text{Discharge from lateral (lph)}}{\text{Length of lateral (m)}}$$

The following tables give allowable lengths for 8 mm, 12 mm, 14 mm & 16 mm pipe at different pressure head and lateral flow rates.

Table 6.3.7 Allowable length of 14 mm and 16 mm pipes (m)

Lateral SDR (lph/m)	Available Pressure Head											
	1 m		2 m		3 m		5 m		10 m		15 m	
	14 mm	16 mm	14 mm	16 mm	14 mm	16 mm	14 mm	16 mm	14 mm	16 mm	14 mm	16 mm
1.0	40	50	45	60	60	80	80	100	120	150	150	180
2.0	30	40	35	50	45	60	60	80	80	100	100	120
4.0	25	30	30	40	35	40	40	50	50	60	60	75
6.0	15	20	20	25	25	30	30	40	40	50	50	60
10.0	10	12	12	15	15	20	20	25	25	35	35	45
15.0	08	10	10	12	12	15	15	20	20	30	30	35
20.00	04	08	05	10	10	12	10	15	15	20	20	25

Note :

The above figures are for flat land (zero slope.) Pipe length adjustments must be made if the slope is above zero. Use lateral pipes along the contour line and shorter sub-main pipe against the slope and longer sub-main down the slope so that discharge variation is within desired uniformity levels. (Flow and friction loss tables are given in Appendix A.)

6.3.8 Design of the sub-main

The sub-main pipe is designed similarly to the lateral lines because it is also a perforated pipe whose discharge reduces along the length of the pipe. Depending on the flow rate, various sizes of PVC / HDPE / LLDPE pipes are used as sub-main pipes in micro irrigation system. For IDEal Drip System klits, 16 mm, 32 mm and 48 mm Lay Flat LLDPE pipe is used for the sub-main pipe. The calculation of the allowable length at different pressure heads and flow rates for 32 mm, 48 mm, 63 mm and 75 mm is given below.

$$\text{Sub-main SDR (lph/m)} = \frac{\text{Lateral SDR (lph/m)} \times \text{Length of the lateral (m)}}{\text{Spacing between two laterals (m)}}$$

$$= \frac{\text{Total Discharge from the Sub main (lph)}}{\text{Length of the sub main (m)}}$$

Table 6.3.8A Allowable length of 32 mm & 48 mm pipes (m)

Submain SDR (lph/m)	Available Pressure Head											
	1 m		2 m		3 m		5 m		10 m		15 m	
	32 mm	48 mm	32 mm	48 mm	32 mm	48 mm	32 mm	48 mm	32 mm	48 mm	32 mm	48 mm
20	40	60	50	50	60	75	70	90	80	120	100	150
40	25	30	30	40	40	50	50	60	60	90	70	120
80	15	20	20	30	25	30	30	45	40	60	50	80
150	07	10	10	15	15	20	20	30	25	40	30	50
300	04	07	06	10	13	17	18	25	22	30	27	40

Table 6.3.8B Allowable length of 63 mm & 75 mm pipes (m)

Sub-main SDR (lph/m)	Available Pressure Head											
	1 m		2 m		3 m		5 m		10 m		15 m	
	63 mm	75 mm	63 mm	75 mm	63 mm	75 mm	63 mm	75 mm	63 mm	75 mm	63 mm	75 mm
50	30		40		50		80		100		120	
100	10	30	25	45	30	55	50	70	60	80	80	100
150	05	15	15	25	20	40	30	50	40	60	60	80
200		10	05	15	10	20	20	35	30	45	40	65
300				10	05	15	10	25	20	35	25	45
400						10	05	15	10	25	15	25
500								10	05	15	10	15

(Flow and friction loss tables given in Appendix A.)

6.3.9 Design of Main Line

Design of the main line involves determining the diameter of the pipe and class / thickness. It depends upon flow rate, operating pressure and topography. As per the irrigation scheduling of the sub-main units, the main line flow can be determined by selecting the sub-mains that will operate concurrently. The main line size is selected so that allowable pressure variations due to frictional losses are within the limit for the economic pipe sizing. Frictional head loss can be calculated using the Hazen-Williams equation as given below.

$$H_l = \frac{15.27\, Q^{1.852}\, L}{D^{4.871}}$$

where H_l is pressure loss due to friction (m);
Q is total discharge in the pipe (lps);
L is length of pipe (m);
and D is inside diameter (cm).

The following table gives main line sizes for different flow ranges and resulting frictional head losses for 10 m of pipe.

Table 6.3.9 Flow range and frictional loss for various main line pipe sizes

Pipe Size (Outside diameter-mm)	16	20	25	32	40	50	63	75
Flow Range (lps)	0.01-0.07	0.07-0.15	0.15-0.25	0.25-0.50	0.50-1.00	1.00-2.00	2.00-3.50	3.50-5.00
Friction Loss (m per 10 m of pipe length)	0.01-0.35	0.10-0.38	0.13-0.32	0.10-0.32	0.10-0.30	0.11-0.40	0.11-0.32	0.13-0.30

6.3.10 Selection of Filter

The filtration requirement depends on the size of the flow path in the emitter, quality of water and flow in the mainline. IMS Kits use screen filters because water is stored in a storage tank. For large systems, depending on water quality, different filters or combination of filters can be used. For large flow requirements filters can be connected in parallel using manifolds so that pressure loss across the filters is within limits. Four types of filters are mainly available in different sizes (filtration area) as described below.

1. Screen (Mesh) Filter: It is made of plastic or metal and different sizes are available for different flow rates from 1 m^3/hr to 40 m^3/hr. It is used for normal water with light inorganic impurities. It is also called a surface filter.

2. Sand (Media) Filter: It is made of M.S. metal and available in different sizes similar to the screen filter. It is used for water with suspended particles and organic impurities like algae. Either sand or gravel can be used as the media for filtration. It is also called a depth filter. and is used in series with the screen filter.

3. Disc Filter: It is made of plastic and has round discs with micro water paths, staked together in a cylinder so that impurities can not pass through the discs. It combines surface and depth filters.

4. Hydro-cyclone: It is made of M.S. metal and has a conical shaped cylinder to give centrifugal action to the flow of water so that heavy impurities settle. It is used in conjunction with the screen filter to filter sandy water along.

6.3.11 Selection of Pump / Total Head Requirement

The head (pressure) required at the inlet of the mainline or filter is calculated as follows:

Head (m) = Operating pressure (m) + Mainline friction loss (m) + fittings loss (m) + Filter loss (m) + (-) Elevation difference (m).

For a centrifugal pump the total head requirement is calculated as follows:

Total Head (m) = Suction head (m) + Delivery head (m) + Operating pressure (m) + Mainline friction loss (m) + fittings loss (m) + Filter loss (m) + (-)Elevation difference (m).

The horsepower requirement is calculated as follows:

$$\text{Horsepower (HP)} = \frac{\text{Flow (lps) x Total Head (m)}}{\text{75 x Motor efficiency x Pump efficiency}}$$

Efficiency of the motor and pump differ for different makes and models. Approximate motor efficiency can be assumed at 80% and pump efficiency at 75% for a mono-block pump. However, in order to procure a pump from the market, the required flow and total head should be mentioned to the supplier / manufacturer so that he can select a suitable model from the same or lower horsepower category.

7. Installation & Commissioning

Installation of IDEal Micro Irrigation Systems is a very simple process. It can be divided in to three stages:

1. Installing water source (bucket, barrel, tank, pump, etc.).

2. Laying of pipes and emitters / micro-tubes / setting up sprinklers.

3. Commissioning

If there is no overhead tank then a water source must be created (i.e. a bucket, barrel, tank, etc.) It has to be installed above ground level on a stable support platform at the required height to achieve minimum pressure requirements for the system (minimum 1 meter). The system then can be connected to the water source. Micro-sprinkler and overhead sprinkler kits can be directly connected with the equivalent discharge outlet of a pump or water supply system. Make sure that the control valve and filter are connected to the system through the main line.

For drip systems, lateral pipes are laid on the ground in a straight line or along the plant rows. Emitters / micro-tubes are pre-fixed on the lateral. They are placed at equal spacing so that plants receive a uniform amount of water. For sprinklers, stakes are used to place them properly. Care should be taken so that dirt, sand etc. does not enter into the pipes while making connections.

Before operating the system, end caps at the end of the laterals and sub-main are released so that if there is dirt in the pipes it is washed away and air is also driven out. Open the control valve and let the water flow freely through the pipes for some time (flush the system). Then close the end caps and ensure that water is coming out from each emitter.

In general, the following activities are involved in the installation of IDEal Micro Irrigation Systems:

1. Study installation sketch
2. Give layout for water tank / filter platform and trenches for pipes if required
3. Check components in the kit / material at site as per the list of materials in the user manual
4. Install water storage tank and filter on the platform
5. Connect filter to the water source / pump and the main line
6. Lay out the main line, sub-main and lateral pipes
7. Cover the pipe trenches if required
8. Place / fix the emitters / sprinklers (if microtubes require inflated lateral pipes then fill the pipes with water then punch holes and fix microtubes)
9. Start the pump / Open the valve and fill the pipes with water
10. Release all end caps / flush valves to clean the sytesm of dirt
11. Check pressure and discharge and ensure all emitters are working
12. Operate according to schedule

8. Maintenance & Troubleshooting

The biggest problem of any micro irrigation system is clogging of emitters. IDEal Micro Irrigation System Kits use very simple emitters that are less prone to clogging due to a wider flow path. Therefore, it requires less maintenance than other drippers. However, periodic and preventive maintenance is essential for smooth system function. The following general checks can be carried out periodically depending on the local condition and water quality:

1. Clogging of emitters / micro sprinklers and wetting pattern
2. Placement of emitters / micro-tubes / micro sprinklers
3. Leakages in pipes, valves, filter, fittings, etc.
4. Flushing & cleaning of filter by opening and cleaning the screen
5. Flushing of sub-main & laterals by releasing the end caps

Apart from physical impurities that can be separated by using a screen filter, there are dissolved chemical (mainly salts) impurities and also biological impurities like algae, bacteria, etc. present in some water sources. If the dissolved salts are more concentrated, they can accumulate and clog the emitters. Hydrochloric acid can be applied to the emitters to flush the salts. If bacteria or algae clogs the system, chlorine treatment in the form of bleaching powder (2 mg per liter) can be added to clean the emitters and inhibit slime growth. Some common problems faced by micro irrigation systems, causes and trouble-shooting required are given in the following tables.

Table 8.1.1 Troubleshooting potential system problems for IDEal Micro Irrigation Systems

Problem	Cause	Troubleshooting
Micro-tube / micro sprinkler / emitter not delivering water.	Clogging due to impurities in water or air bubble in micro-tube	1. Take out micro-tube from lateral pipe and shake it or blow it so that the dirt or trapped air comes out. If it is a different type of emitter / micro sprinkler, open it and clean it with a needle so that dirt is removed. Then fix the emitter and check it is working. 2. Check the filter screen and gasket for any possible leakage and if required, replace them.
Leakage in lateral, sub-main or main pipe	Cut in pipe due to mechanical damage, rodents, etc.	Cut the pipe at the place of damage and connect it by using joiner / connector. For large diameter pipes, if joiners are not available then a service saddle can be used.
Leakage in fittings of lateral pipe.	Pipe expansion or frequent use	Cut the pipe end for the expanded portion and insert the fitting in it again. If the fitting is too loose for the pipe diameter it can be adjusted by heating it.
Reduced flow of water from emitter.	1. Caked filter 2. Pipe leakage 3. Open end cap	1. Clean the filter screen. 2. Repair pipe leakage as mentioned above. 3. Tighten the end.

9. Frequently Asked Questions on IDEal Micro Irrigation Systems

Table 9.1.1 Answers to questions about IDEal Micro Irrigation Systems

Question	Answer
Water requirement of Micro Irrigation System	It will depend on climate, soil, crop, etc. Approximately it can be equal to the evapo-transpiration multiplied by the canopy factor or percent wetted area.
Expansion / Customization of Kit	Lateral pipes can be increased in length as shown in table 5.1. Alternately, additional kits can be attached to the same water source.
Life of components	The life of most plastic components is a minimum of five years. It can last up to ten years if maintained properly.
Water saving	Most drip systems save water application up to 50% as compared with traditional systems.
Spacing of micro-tube / emitters / micro sprinklers / mini sprinklers / impact sprinklers	For closely spaced crops like onion or garlic drippers should be close enough to form the wetting strip (between 30 to 45 cm). For widely spaced crops, one or more drippers can be used per plant depending on plant spacing and wetting required. Normally, sprinklers are space at radius of coverage area of the wetting pattern for better uniformity.
Water storage required	The capacity of water storage for a gravity system should be equal to one day retention of the daily water requirement. It can be less if the frequency of water filling is higher or continuous.
Root development when using drip irrigation	The roots have a tendency to reach for moisture. Therefore, the roots are very well developed when using drip irrigation. Micro Irrigation Systems provide the proper soil-air-water ratio for root respiration.
Application of drip to existing plants	Micro Irrigation System can be applied to existing plants for better yield. Care should be taken if moisture stress is required by some crops to induce flowering.
Water application at the time of sowing	It is better to provide enough water to form complete wetting so that all the seeds/seedlings have access to moisture.
Reasons for increase in yield / quality	Since water is given at regular but frequent intervals and at a required quantity as compared with traditional systems, plants have better metabolism and produce a better crop in terms of both quality and quantity. The soil-water-air ratio is also favorable for most cash crops. Micro Irrigation keeps the soil warmer than conventional irrigation.

contd...

Question	**Answer**
Pressure head required for IDEal Micro Irrigation Kits	The pressure head or height of water source will depend on the area covered or distance of remotest emitters from the source. Approximately 1m for 100 sq.m., 1.5 m for 500 sq.m. and 2 m for 1000 sq.m. For Micro and Mini Sprinklers minimum operating pressure is 5 m. For impact sprinklers minimum operating pressure is 10 m.
Use of IDEal Micro Irrigation System on undulated area	If there are terraces formed on hill slopes or undulated area, one or more drip kit should cover a single terrace, which is evenly leveled. A separate kit should be used for a terrace on the upward or downward side. Operate one terrace at a time to get uniform application. If more terraces have to be irrigated at a time then the flow for downward terraces should be decreased with the help of a valve or orifice so that an equal quantity of water is supplied to each terrace.
Length of micro-tube	For vegetables where micro-tubes are provided on both sides of the lateral, it should be sufficient to reach each row. For widely spaced crops it should confirm to required discharge at a given pressure head.
Damage to lateral pipes due to rodents, etc.	Lateral pipe should be cut and damaged portion removed. Re-connect the lateral with the help of the connector.
Theft of IDEal Micro Irrigation System	Try to bury the maximum length of pipes under the ground. The lateral and sub-main pipes being perforated with holes will be less prone tor theft.
Shifting of micro-tube system at the end of the season	After the crop has been harvested, the drip system should be stored properly so that it is not damaged mechanically or by rodents in the store / field. Hanging it on a wooden pillar can protect it from the rodents.
Use of IDEal Micro Irrigation System for different crops	The spacing of most vegetable crops is the same or in multiples of the minimum. Therefore, the drip kit can be utilized for various spacing of crops.

Table A.1 Flow and friction Loss for 16 mm lateral pipe with 25 cm long microtube

Microtube Spacing		ROW / LATERAL LENGTH - Meters (m)									
		10		20		30		40		50	
		LATERAL FLOW - lpm and HEAD LOSS - m									
Inch	cm	lpm	m	lpm	m	lpm	m	lpm	m	lpm	m
		AVERAGE PRESSURE HEAD - 0.5 m (q_a=2.84)									
12	30	1.58	0.01	3.16	0.07	4.73	0.21	6.31	0.45	7.89	0.84
18	45	1.05	0.00	2.10	0.03	3.16	0.10	4.21	0.22	5.26	0.41
24	60	0.79	0.00	1.58	0.02	2.37	0.06	3.16	0.13	3.94	0.25
30	75	0.63	0.00	1.26	0.01	1.89	0.04	2.52	0.09	3.16	0.17
36	90	0.53	0.00	1.05	0.01	1.58	0.03	2.10	0.07	2.63	0.12
		AVERAGE PRESSURE HEAD - 1.00 m (q_a=4.59)									
12	30	2.55	0.02	5.10	0.16	7.65	0.48	10.20	1.05	12.75	1.94
18	45	1.70	0.01	3.40	0.08	5.10	0.23	6.80	0.52	8.50	0.95
24	60	1.28	0.01	2.55	0.05	3.83	0.14	5.10	0.31	6.38	0.58
30	75	1.02	0.00	2.04	0.03	3.06	0.10	4.08	0.21	5.10	0.39
36	90	0.85	0.00	1.70	0.02	2.55	0.07	3.40	0.15	4.25	0.28
		AVERAGE PRESSURE HEAD - 1.5 m (q_a=6.10)									
12	30	3.39	0.04	6.78	0.26	10.17	0.78	13.56	1.72	16.94	3.18
18	45	2.26	0.02	4.52	0.13	6.78	0.38	9.04	0.85	11.30	1.57
24	60	1.69	0.01	3.39	0.08	5.08	0.23	6.78	0.51	8.47	0.95
30	75	1.36	0.01	2.71	0.05	4.07	0.16	5.42	0.35	6.78	0.64
36	90	1.13	0.01	2.26	0.04	3.39	0.11	4.52	0.25	5.65	0.47
		AVERAGE PRESSURE HEAD - 2.00 m (q_a=7.46)									
12	30	4.14	0.05	8.29	0.36	12.43	1.11	16.58	2.45	20.72	4.53
18	45	2.76	0.03	5.53	0.18	8.29	0.55	11.05	1.21	13.81	2.23
24	60	2.07	0.02	4.14	0.11	6.22	0.33	8.29	0.73	10.36	1.35
30	75	1.66	0.01	3.32	0.07	4.97	0.22	6.63	0.49	8.29	0.91
36	90	1.38	0.01	2.76	0.05	4.14	0.16	5.53	0.36	6.91	0.66
		AVERAGE PRESSURE HEAD - 3.00 m (q_a=9.91)									
12	30	5.51	0.09	11.01	0.60	16.52	1.83	22.02	4.03	27.53	7.44
18	45	3.67	0.04	7.34	0.29	11.01	0.90	14.68	1.98	18.35	3.66
24	60	2.75	0.03	5.51	0.18	8.26	0.54	11.01	1.20	13.76	2.21
30	75	2.20	0.02	4.40	0.12	6.61	0.37	8.81	0.81	11.01	1.50
36	90	1.84	0.01	3.67	0.09	5.51	0.27	7.34	0.59	9.18	1.09

Table A.2: Flow and friction loss for 63 mm sub-main pipe

Lateral Spacing		SUB-MAIN LENGTH - METERS (m)									
		20 -m		30 -m		40 -m		50 -m		60 -m	
		SUB-MAIN FLOW - lpm and HEAD LOSS - m									
Inch	cm	lpm	m	lpm	m	Lpm	m	lpm	m	lpm	m
		AVERAGE LATERAL FLOW (Q_l=4.0 lpm)									
24	60	2.22	0.04	4.44	0.24	6.67	0.75	8.89	1.65	11.11	3.04
30	75	1.78	0.02	3.56	0.17	5.33	0.51	7.11	1.11	8.89	2.06
36	90	1.48	0.02	2.96	0.12	4.44	0.37	5.93	0.81	7.41	1.50
48	120	1.11	0.01	2.22	0.07	3.33	0.22	4.44	0.49	5.56	0.90
		AVERAGE LATERAL FLOW (Q_l=6.0 lpm)									
24	60	3.33	0.07	6.67	0.50	10.00	1.52	13.33	3.35	16.67	6.19
30	75	2.67	0.05	5.33	0.34	8.00	1.03	10.67	2.27	13.33	4.19
36	90	2.22	0.04	4.44	0.24	6.67	0.75	8.89	1.65	11.11	3.04
48	120	1.67	0.02	3.33	0.15	5.00	0.45	6.67	1.00	8.33	1.84
		AVERAGE LATERAL FLOW (Q_l=8.0 lpm)									
24	60	4.44	0.12	8.89	0.82	13.33	2.51	17.78	5.54	22.22	10.24
30	75	3.56	0.08	7.11	0.56	10.67	1.70	14.22	3.75	17.78	6.93
36	90	2.96	0.06	5.93	0.41	8.89	1.24	11.85	2.73	14.81	5.03
48	120	2.22	0.04	4.44	0.24	6.67	0.75	8.89	1.65	11.11	3.04
		AVERAGE LATERAL FLOW (Q_l=10.0 lpm)									
24	60	5.56	0.18	11.11	1.22	16.67	3.71	22.22	8.19	27.78	15.12
30	75	4.44	0.12	8.89	0.82	13.33	2.51	17.78	5.54	22.22	10.24
36	90	3.70	0.09	7.41	0.60	11.11	1.83	14.81	4.03	18.52	7.44
48	120	2.78	0.05	5.56	0.36	8.33	1.10	11.11	2.43	13.89	4.50
		AVERAGE LATERAL FLOW (Q_l=12.0 lpm)									
24	60	6.67	0.25	13.33	1.67	20.00	5.11	26.67	11.27	33.33	20.81
30	75	5.33	0.17	10.67	1.13	16.00	3.46	21.33	7.62	26.67	14.08
36	90	4.44	0.12	8.89	0.82	13.33	2.51	17.78	5.54	22.22	10.24
48	120	3.33	0.07	6.67	0.50	10.00	1.52	13.33	3.35	16.67	6.19
		AVERAGE LATERAL FLOW (Q_l=14.0 lpm)									
24	60	7.78	0.33	15.56	2.19	23.33	6.69	31.11	14.75	38.89	27.25
30	75	6.22	0.22	12.44	1.48	18.67	4.53	24.89	9.98	31.11	18.44
36	90	5.19	0.16	10.37	1.08	15.56	3.29	20.74	7.26	25.93	13.40
48	120	3.89	0.10	7.78	0.65	11.67	1.99	15.56	4.39	19.44	8.10

Abbreviation	Description
IDE	International Development Enterprises
IDS	IDEal Drip System
ISS	IDEal Sprinkler System
IMS	IDEal Micro Irrigation System
ET	Evapo-transpiration
hp	Horse Power
LPH	Liter per Hour
LPS	Liter per Second
LPH per meter	Liter per hour per meter
ha	Hectare
ft	Feet
inch	Inches
mm	Millimeter
cm	Centimeter
m	Meter
Sq.m	Square meter
PVC	Polyvinyl chloride
PE	Polyethylene
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene

REFERENCES

Adhikari, Deepak. 2000 Simplified and Low Cost Drip Irrigation Manual, International Development Enterprises, Kathmandu, Nepal.

Keller, Jack and Ron Bliesner. 2000. Sprinkler and Trickle Irrigation. ISBN: 1-930665-19-9. Blackburn Press, Caldwell, New Jersey.

Proceedings of Drip and Sprinkler Workshop 1994, Jalgaon (M.S.), India.

Proceedings of Micro Irrigation Congress 1995, Orlando, FL, USA.

Suryawanshi, Sudarshan. 2000. Affordable Micro Irrigation Technology, International Devleopment Enterprises, Delhi, India.

IDE

INTERNATIONAL DEVELOPMENT ENTERPRISES

INTERNATIONAL DEVELOPMENT ENTERPRISES

10403, West Colfax, Suite 500, Lakewood, CO 80215, USA

Tel : 303-232-4336 www.ide-international.org

CGIAR Challenge Program on WATER & FOOD