# Micro Irrigation fro Efficient Use of Natural Resources

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## Introduction

The terms "drip", "trickle" and "spray" irrigation, common in many quarters in the last 15 years, have been supplanted by the term "micro irrigation", recently adopted by the American Society of Agricultural Engineers. Micro irrigation includes all methods of frequent water application, in small flow rates, on or below the soil surface. Ideally, the volume of water is applied directly to the root zone in quantities that approach the consumptive use of the plants. Through good management of the micro irrigation systems the root zone moisture content can be maintained near field capacity throughout the season providing a level of water and air balance close to optimum for plant growth. In addition, nutrient levels which are applied with water through the system can be controlled precisely. During the dry season in humid areas, or in arid climates, micro irrigation can have a significant effect on quality and quantity of yield, pest control and harvest timing.

**Advantages of Micro Irrigation Systems:** Micro irrigation systems have many potential advantages when compared with other irrigation methods.

1. Water Savings
Irrigation water requirements can be smaller with micro irrigation 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. The losses due to the evaporation from the soil are significantly reduced compared with other irrigation systems since only a small surface area under the plant is wetted and it is usually well shaded by the foliage. 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. Smaller Flow Rates
Since the rate of water application in micro irrigation systems is significantly lower than in other systems, smaller sources of water can be used for irrigation of the same acreage. The delivery pipes, the pump, and other components of the system can be smaller and therefore more economical. The systems operate under low pressure (5-30 psi) and require less energy for pumping than high pressure systems.

3. Application of Chemicals
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.
There is also an advantage to the frequent application of fertilizers through the system in Florida's humid climate. In case of rain, only a small portion of recently applied fertilizer will be washed out and it can be easily replaced through the irrigation system. 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.

4. Water Sources with High Salt Content

A significant advantage of micro irrigation is that water with relatively high salt content can be used by the system. For optimum plant growth a certain range of total water potential in the root zone must be maintained. The potential defines how difficult it is for a plant to extract water from the soil. Large negative numbers are characteristic of very dry soils with low total water potentials while potentials near zero reflect soils near saturation. The total water potential in the root zone is a sum of the matric potential and osmotic potential. Since matric potential is close to zero under micro irrigation (high moisture content) the osmotic potential component can be a relatively large negative value, indicating high salt content, without harmful effect on plant growth. This is not true for other irrigation systems.

5. Improved Quality of the Crop

Micro irrigated plants are supplied very frequently with small amounts of water and the stress due to the moisture fluctuation in the root zone is reduced to the minimum, often resulting in larger and better quality yield.

6. Adaptation to any Topography

Micro irrigation systems can operate efficiently on hilly terrain if appropriately designed and managed. Well managed micro irrigation system will not create runoff even on hilly terrain.

7. Additional Advantages of Micro-Irrigation Systems

During dry seasons or in arid climates disease and insect damage can be reduced under micro irrigation system since the foliage of the plant is not wetted. With a small portion of soil surface being watered, field operations can be continued during irrigation. The water distribution is not affected by the wind for drip irrigation. However, wind can have some effect on jet spray patterns.

Since only the portion of the soil surface is wetted/water uptake by the weeds between the rows can also be significantly reduced. Micro irrigation systems can also be extensively automated/ decreasing labor and operating costs.

**Potential Problems in Micro Irrigation**

To operate satisfactorily, a micro irrigation system have to be correctly designed and managed to account for the physical properties of soil, quality of irrigation water, and water requirement of the grown plants. This type of system definitely requires a higher management level than other irrigation systems. With all the advantages listed above, a micro irrigation system is not a system without problems.

1. Clogging

One of the biggest problems encountered under micro irrigation is clogging of the 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 is 200 mesh screen) even with a good quality water supply.

2. Moisture Distribution

Moisture distribution depends largely on the soil type being irrigated by the micro system. In some soils, for example deep sands, very little lateral water movement (low capillary forces) can create many problems. The wetted volume has a shape approaching a cylinder rather than a hemisphere since gravity forces dominate. 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. As a result, coarse sands will require much closer spacing of emitters than fine soils. In general, for any soil, the number of emitters and their spacing must be based on the geometry of wetted soil volume.

It is important to realize that the micro irrigation system wets only a limited portion of the potential soil-root volume. Most of the plants can perform very well under these conditions. However, there is a minimum volume of roots which has to be wetted or a reduction in yield will be observed.

3. Salt Buildup

Micro irrigation systems can use saline water. However, a problem may occur from salts accumulating at the edges of the wetted zone during prolonged dry periods. Light rain can wash these salts into the root zone and cause injury to the plants. In arid climates, where the rainfall is less than 10 inches per year, an additional irrigation system (sprinkler or surface) may be necessary to leach accumulated salts from the soil between growing seasons. In areas with heavy rainfall the salts will be washed out of the root zone before significant accumulation occurs.

4. Initial Cost

The initial investment and maintenance cost for a micro-irrigation system may be higher than for some other irrigation methods. Filters, chemical injectors and possible automation components add to the cost of a micro irrigation system. Actual costs will vary considerably depending on the selection of a particular micro system, required filtration equipment, water quality, water treatment and selection of automation equipment.

Components of Microirrigation System

A. System components for drip irrigation scheme

1. Head control unit
a) Non-return valve
b) Air valve
c) Vacuum breaker valve
d) Filtration unit (Screen / Disc / Sand / Hydrocyclone)
e) Fertigation unit (Fertilizer tank)
f) Throttle (Gun metal) valve
g) Water meter (optional)
h) Pressure gauge
i) Other fittings & accessories

2. Water carrier system
a) HDPE/PVC pipeline for main
b) HDPE/PVC pipeline for submain
c) Control (PVC or PP) valve
d) Flush valve
e) Other fittings & accessories

3. Water distribution system
a) Online dripper
b) Plain lateral
c) Emitting pipe
d) Spaghetti (for connecting emitter to lateral)
e) Grommet
f) Nipple
g) Start connector
h) End cap

B. Sprinkler irrigation system

HDPE Pipes with quick action coupler of 6m long
Sprinkler coupler with foot batten assembly
Sprinkler nozzles (1.7 to 2.8 kg/cm$^2$)
Riser pipe 20mm diameter & 75cm long
Connecting nipple
Bend with coupler 90$^0$
Tee with coupler
End plug

C. Gravity fed Family drip systems

Control Valve
PE pipe for main/submain
Emitting pipe
Filter
Tank (200 L and above)
Grommet
Start connector
End cap
Fittings & accessories

**Head control unit**

**a) Non-return valve**
Check valves or also called non-return valves, permit flow in one direction only and prevent reversal flow in piping by means of an automatic check mechanism. They come in two basic types: the swing check, which can be installed in horizontal or vertical piping; and the lift check, for use in horizontal lines only. Water flow keeps the check valves open, and gravity and reversal of flow close them automatically. They are placed in-line at the head control unit immediately after the pump. Swing checks are used with gate valves, lift checks with disk valves. Check valves are made of several metal materials and brass, and are screw type (female joints) quoted in inches from _ to 4 in, at a PN of 16.0 bars.

**b) Air valves.** These valves are of great importance as they protect the pipe network from damage by trapped air in the system or from collapse due to a vacuum. If improperly chosen or located in a wrong place, it can also cause severe functional problems.

The presence of free air in water installations causes many difficulties in the piping system at start-up, during operation and when draining the system. Air valves are needed so that air can be either released from or admitted into the pipelines. Its operation and air flow rate cannot be influenced either by the system operator or by the performance of any other appliance. There are three main kinds of air valves:

In addition to the above air valves, small vacuum breakers of 1/2 inch are available for preventing vacuums in drip laterals laid on the soil surface, thus protecting them from clogging.

Air valves are manufactured for high working pressures of at least 10.0 bars PN. They are installed on-line with threaded internal or external joints.

**Filtration unit**: The filtration of the irrigation water is essential in order to avoid blockage damage to the micro-irrigation emitters. The type of filter used depends on the kind of impurities contained in the water and the degree of filtration required on the emitters. Their size should be the most economical with the lowest friction losses ranging from 0.3-0.5 bars. The following kinds of filters are available:

**A. Gravel filters.** These filters, also called media filters, are closed cylindrical tanks which contain a gravel grain of 1.5-3.5 mm or a basalt sand filter bed. Where the irrigation water source is an open reservoir, they are installed at the beginning of the head control of the system. Water entering the tank from top passes through the gravel bed, which traps the large particles of unbroken organic matter, mostly algae, and exits through the outlet at the bottom of the tank. They are equipped with the necessary inlet, outlet and drain valves, and a back-flushing arrangement. The filter body is epoxy coated metal, minimum 8.0 bars PN, and is 50-180 cm high and 40-100 cm in diameter. They are available in threaded connection sizes of 1-8 in.

**B. Hydrocyclone (sand separator) filters.** These are closed conical metal tanks placed at the beginning of the head control unit where needed. They separate sand or silt from well or river water through the creation of a centrifugal force by a vortex flow inside the filter. This force drives the solids downward to a collecting chamber attached below and
lets the clean water out. They are epoxy coated, PN 8.0 bars, and are available in threaded connection sizes of _-8 in.

**C.Screen type filters.** These are used for final filtration as a safeguard for either moderate quality water or following a primary filtration with gravel or hydrocyclone filters. They are installed at the end of the head control before the main pipeline. They are made of epoxy coated metal or high engineering plastics in various cylindrical shapes (horizontal on-line, vertical angle, etc.), and are equipped with interchangeable perforated filtering elements, inlet, outlet and drain valves and pressure inspection gauges. They can withstand a working pressure (PN) of 8.0 bars. The degree of filtration ranges from 60 to 200 mesh (75 microns). They are available in sizes of _-4 in. Smaller sizes are made of reinforced plastic.

**Disk type filters.** They are cylindrical, made of reinforced plastic, horizontal in-line or vertical angle-shaped. The filtering elements consist of stacks of grooved plastic rings with multiple intersections providing a three dimensional filtration of high level. They are very effective in removing all kinds of impurities of inorganic and organic origin, algae included. The degree of filtration can range from 40 to 600 mesh (400-25 microns). They are available in all sizes (_-6 in), PN 8.0 bars, with threaded joints. They are placed at the end of the control unit before the main pipeline.

**Fertiliser Tank**

Fertilizers are applied with the irrigation water through the system using special devices called fertilizer injectors installed at the head control.There are three main types of fertilizer injectors: closed tank, Venturi type and piston pump. All of them are water driven by the operating pressure of the system.

**A. Fertilizer (closed) tank.** This is a cylindrical, epoxy coated, pressurized tank, resistant to the system's pressure, and connected as a bypass to the supply pipe of the head control. It is operated by differential pressure created by a partially closed valve, placed on the pipeline between the inlet and the outlet of the tank. Part of the flow is diverted to the tank entering at the bottom. It mixes with the fertilizer solution and the dilution is ejected into the system. The dilution ratio and the rate of injection are not constant. The concentration of fertilizer is high at the beginning and very low at the end of the operation. However, this apparatus is still in service on a very small scale in some countries because of its low cost and easy manufacture
.

**B. Venturi type.** This is based on the principle of the Venturi tube. A pressure difference is needed between the inlet and the outlet of the injector. Therefore, it is installed on a bypass arrangement placed on an open container with the fertilizer solution. The rate of injection is very sensitive to pressure variations, and small pressure regulators are sometimes needed for a constant ejection. Friction losses are approximately 1.0 bar. The injectors are made of plastic in sizes from 2 in and with injection rates of 40-2 000 litres/h. They are relatively cheap compared to other injectors.

**Drippers.** The drippers are small-sized emitters made of high quality plastics. They are mounted on small soft PE pipes (hoses) at frequent spaces. Water enters the dripper emitters at approximately 1.0 bar and is delivered at zero pressure in the form of continuous droplets at low rates of 1.0-24 litres/h. Drippers are divided into two main groups according to the way they dissipate energy (pressure):
• orifice type, with flow areas of 0.2-0.35 mm2;
• long-path type, with relatively larger flow areas of 1-4.5 mm2.
Both types are manufactured with various mechanisms and principles of operation, such as a vortex diode, a diaphragm or a floating disc for the orifice drippers, and a labyrinthine path, of various shapes, for the long-path ones. All the drippers now available on the market are turbulent flow ones. Drippers are also characterized by the type of connection to the lateral: on-line, i.e. inserted in the pipe wall by the aid of a punch; or in-line, where the pipe is cut to insert the dripper manually or with a machine.
On-line multi-exit drippers are also available with four to six 'spaghetti' type tube outlets.

**Drip tapes.** These are thin-walled integral drip lines with emission points spaced 10, 20, 30, 45 cm or any other distance apart, delivering lower quantities of water than the usual drippers at very low pressures, i.e. 0.4-1.0 litres/h at 0.6-1.0 bar. They are integrated drip lines where the drippers are built in the pipe walls at the desired spacing during the manufacturing process. They are ready-made dripper laterals with a very high uniformity of application. Drip tapes are made of LDPE or other soft PE materials in various iameters from 12 to 20 mm and in several wall thicknesses (0.10-1.25 mm). They are less susceptible to mechanical and biological blockages than conventional drippers are.

**Pressure compensated (PC) emitters.** Several sprinklers, drippers and other water micro-emitters are available with built-in flow regulators. These emitters deliver a constant flow of water at any pressure exceeding the fixed operating one. Uniform rates of discharge are achieved along the laterals regardless of the number of emitters, spacing, length of line or elevation, where excessive pressure is available. Therefore, pressure variations in the laterals due to friction losses can exceed 20 percent. Thus, less expensive smaller diameter pipes can be installed in certain cases. However, the self-regulated emitters, called pressure compensated, are normally operated under pressures exceeding the fixed operational pressures and cost more than the conventional ones.

**Sprinklers.** Most of the agricultural sprinklers are the hammer-drive, slow rotating impact type, single or twin nozzle. The sprinklers shoot jets of water into the air and spread it to the field in the form of raindrops in a circular pattern. They are available in various nozzle sizes, flow discharges, operating pressures and wetted diameters or diameter coverage, full circle or part circle. They are classified as low, medium and highpressure/capacity, as shown in Table 5; according to the height of the water jet above the nozzle, they are divided into low angle (4º-11º), or high angle (20º-30º). They are made of brass or high engineering plastics with internal or external threaded connections of _-1_ in. They are installed vertically on small diameter riser pipes, 60 cm above ground, fitted on the laterals. The sprinkler spacing in the field is rectangular or triangular at distances not exceeding 60 percent of their diameter coverage. Filtration requirements, where necessary, are about 20 mesh.

**Sprinkler classification**

| Agriculture sprinklers (two nozzle) | Nozzle size mm | Operating pressure (bars) | Flow rate (m_/h) | Diameter coverage (m) |
|---|---|---|---|---|
| Low pressure | 3.0-4.5 x 2.5-3.5 | 1.5-2.5 | 0.3-1.5 | 12-21 |
| Medium pressure | 4.0-6.0 x 2.5-4.2 | 2.5-3.5 | 1.5-3.0 | 24-35 |
| High pressure | 12.0-25.0 x 5.0-8.0 | 4.0-9.0 | 5.0-45.0 | 60-80 |

**Microsprinklers.** These water emitters are small plastic sprinklers of low capacity with flow rates less than 300 litres/h. Their main characteristics are their rapid rotation/whirling, less than a minute per rotation, the very small size of the water drops and the low angle of the water jet above nozzle. They have only one nozzle, of about 2.0 mm. They discharge 150-250 litres/h at 2.0 bars operating pressure. They are full circle and the wetted diameter is only 10-12 m. Mounted at a height of 60 cm on metallic or plastic rods inserted into the ground, they are connected to PE laterals (25 or 32 mm) through small flexible tubes 7 mm in diameter and 80 cm long. The spacing arrangement in the field is the same as for conventional sprinklers. The spacing does not exceed 6.0 m, i.e. 50 percent of the wetting diameter. The filtration requirements are about 60 mesh (300 microns).

**Spitters, micro-jets and sprayers.** These are small plastic emitters with a low water discharge at a low angle in the form of fine drops in a sectorial or full circle pattern. They are mainly used for tree crops. They are of various mechanisms with a wide range of flow rates and water diameters. They have a small passage diameter, thus filtration of the water is essential. Their main performance characteristics are:

- operating pressure: 1.5-2.0 bars;
- flow rate: 35-250 litres/h (generally 150 litres/h);
- wetting diameter: 3-6 m;
- precipitation rate: 2-20 mm/h (generally 4-8 mm/h);
- filtration requirements: 60-80 mesh (250-200 microns).

Their heads are fixed to small plastic wedges 20-30 cm above ground and they are connected to the PE laterals with 7-9-mm flexible plastic tubes 60-120 cm long and a barbed plunger. They are placed one per tree, 30-50 cm apart.

**System design**

The engineering and hydraulic design procedure is almost the same in all kinds of pressurized irrigation systems. It consists of a series of interlinked calculations. The various stages are outline below.

**Selection of the water emitter** (sprinkler, dripper, minisprinkler, bubbler, hose, etc.) according to the crop, irrigation method and requirements:

- type, flow rate, operating pressure, diameter coverage;
- spacing and number per lateral line.

**Design of the laterals**

- length, direction, spacing and total number of lateral lines (in solid systems) or lateral positions (in semi-permanent installations);
- flow of the lateral = number of emitters per lateral x emitter flow rate;
- number of laterals operating simultaneously = system flow/flow of lateral;
- number of shifts to complete one irrigation = total number of lateral

lines or positions ÷ number of laterals operating simultaneously; Duration of application = irrigation dose in millimetres ÷ application rate in millimetres per hour, or irrigation dose in cubic metres per hour ÷ system flow in cubic metres per hour.

**Determination of the size of the pipelines**

**Lateral lines**

It is important to understand the water emitter's functions and principle of operation before commencing the design process. One of the main characteristics of all types of emitters is the relationship between flow rate and operating pressure, which is usually expressed by the empirical formula:

$$q = k\ d\ H\ *$$

where q is the emitter discharge, k and d are coefficients (constants), H is the pressure at the emitter and * is an exponent characterized by the emitter flow regime and the flow rate curve as a function of the pressure. The lower the value of *, the less the influence of pressure variations on the emitter flow rate along the lateral line. Most of the water emitter flow regime is fully turbulent with an exponent value equal to 0.5. Thus, the difference in discharge is half the difference in pressure, when the ratio of the two different pressures is < 1.3/1.0. In order to ensure a high uniformity of water application over the field, the differences in the discharge of the emitters should be kept to the minimum possible and in no case exceed 10 percent. These criteria were established by J. Christiansen for sprinklers and are now applied in all pressurized systems. As a general rule, the maximum permissible difference in pressure between any two emitters in operation should be no more than 20 percent. The lateral lines with emitters must be of a size that does not allow a loss of head (pressure) due to friction of more than 20 percent.

The loss of head due to friction (friction losses) in lateral pipes is taken from a graph or a table. It is not the true figure as the flow is distributed en route through the emitters. In order to compute the actual losses the above figure is multiplied by Christiansen's reduction coefficient, F, to compensate for the water delivered along the lateral line. The F values depend on the number of the outlets uniformly spaced along the pipeline Three different series of F values exist corresponding to the Q exponent (m) of the three main friction loss formulas: Hazen Williams, 1.85; Scobey, 1.9; and Darcy Weisbach, 2.0. Moreover, lower values are taken if the distance of the first outlet is half the spacing of the outlets, etc. However, the differences between the various F values are almost negligible.

Due to the multiplicity of emitters with variable flow regimes and other factors affecting the pressure/discharge relation along the laterals in the field, such as local minor losses that occur at the connection of the emitters on small-sized pipes and temperature fluctuations, the manufacturers should always provide charts for the optimum length of emitter laterals, based on the size of pipe, emitter spacing, operating pressure, flow rate and slope.

**Manifolds, submain and main pipelines**

On the manifolds, whether these pipelines are the submains or the mains as well, a number of laterals are fed simultaneously. The flow of the line is distributed en route, as in the laterals with the emitters. Consequently, when computing the friction losses, Christiansen's reduction coefficient, F, is also considered. The mains, submains and all hydrants are selected in such sizes that the friction losses do not exceed approximately 15 percent of the total dynamic head required at the beginning of the system's piped network. On level ground, these friction losses amount to about 20 percent of the emitter's fixed operating pressure. This is a practical rule for all pressurized systems to achieve uniform pressure conditions and water distribution at any point of the systems. The above figure should not be confused with or related in any way to the maximum permissible friction losses along the laterals.

Another important element is the flow velocity in the mains, submains and hydrants. This value should always be kept below 1.7 m/s_ in plastic tubes and a maximum of 2 m/s_ in other pipes (steel, aluminium, etc.).

**Head control**

The component parts of the head control and their size are in accordance with the system requirements. In micro-irrigation systems the units are complete with filters and fertilizer injectors, while in sprinkler and hose irrigation systems the head controls are simple with the minimum of equipment. The friction losses in the various component parts vary accordingly from 3 to 10 m. The friction loss formulas are empirical and include many variables and correction factors. In calculating the pipe friction losses from equations, extensive practical experience is needed. In view of the fact that great accuracy is not possible due to the unpredictable changes in pipe roughness, water viscosity, nozzle wear, clogging, etc., the use of friction loss tables and nomographs is recommended.

**Some of the recommended irrigation system type for various crops**

| S. No. | Crop | Irrigation system | Spacing | Lateral spacing (m) | Dripper spacing (m) | Drippers per plant | Dripper discharge (LPH) |
|---|---|---|---|---|---|---|---|
| 1. | Mango | Drip – online | 10m x 10m | 10m | --- | 4 | 8 |
| | | Drip – online | 9m x 9m | 9m | --- | 4 | 8 |
| | | Drip – online | 8m x 8m | 8m | --- | 4 | 8 |
| | | Drip – online | 7m x 7m | 7m | --- | 4 | 8 |
| | | Drip – online/ inline | 5m x 5m | 5m | --- | 4 | 8 |
| 2. | Sapota | Drip – online | 8m x 8m | 8m | --- | 4 | 8 |
| 3. | Coconut | Drip – online | 8m x 8m | 8m | --- | 4 | 8 |
| 4. | Cashewnut | Drip – online | 6m x 6m | 6m | --- | 4 | 8 |
| 5. | Sweet orange | Drip – online | 6m x 6m | 6m | --- | 4 | 8 |
| 6. | Acid lime | Drip – online | 6m x 6m | 6m | --- | 4 | 8 |
| 7. | Guava | Drip – online | 6m x 6m | 6m | --- | 4 | 8 |
| 8. | Custard apple | Drip – online | 6m x 6m | 6m | --- | 4 | 8 |
| 9. | Ber | Drip – online | 6m x 6m | 6m | --- | 4 | 8 |
| 10. | Pomegranate | Drip – online | 4.5m x 2.7m | 4.5m | --- | 2 | 8 |
| 11. | Grapevine | Drip – inline | 2.7m x 1.5m | 2.7m | 0.4m | --- | 2 |
| | | Drip - online | 2.7m x 1.5m | 2.7m | -- | 2 | 4 |