DIY unpowered uniform drip irrigation on sloping land

Dripper assembly with 20 drippers

Bernie Omodei

Measured Irrigation

5/50 Harvey Street East, Woodville Park SA 5011

Mobile 0403 935277

Email bomodei@measuredirrigation.com.au

Website www.measuredirrigation.com.au

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1. Introduction

This publication is designed to assist smallholders to install a state of the art irrigation system on sloping or uneven land at an affordable cost. Most drip irrigation applications on sloping land use PC (pressure compensated) drippers. A high pressure pump is usually required to ensure that all drippers within each zone are within the pressure range recommended by the manufacturer for pressure compensation. Furthermore, many zones are usually required to ensure that the drippers within each zone are within the pressure range recommended by the manufacturer for pressure compensation.

All of the above requirements for PC drippers make drip irrigation on sloping land from a header tank (or elevated water supply) very expensive.

This publication demonstrates how drip irrigation on sloping land from a header tank (or elevated water supply) can use NPC (non pressure compensated) drippers without compromising irrigation uniformity. It is assumed that the same drippers are used throughout the irrigation application. The irrigation controller is an Unpowered Terracotta Valve.

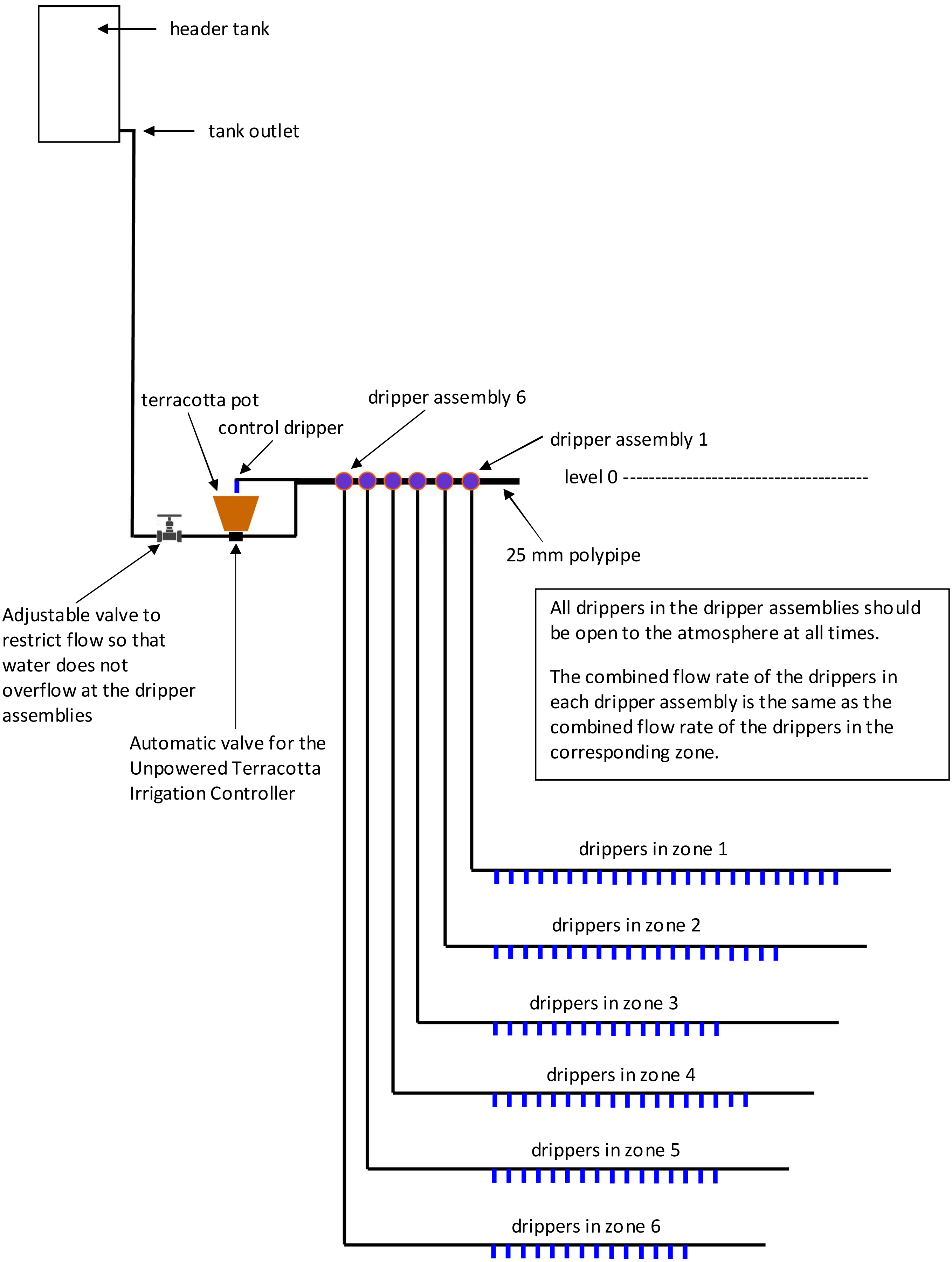
Some key features are listed below.

1. The installation cost is a fraction of the cost of an equivalent PC system.
2. Excluding the refilling of the header tank, the irrigation system is completely unpowered (no batteries, no solar panels, no electronics, no computers, and no WiFi).
3. A small low pressure water transfer pump may be required to refill the header tank between irrigation events.
4. Provided that the irrigation system is designed so that frictional head loss along each lateral is negligible, then irrigation uniformity for the entire irrigation system can be achieved.
5. Provided that the control dripper on the Unpowered Terracotta Valve has the same emitter discharge exponent as the irrigation drippers, the water discharged from each irrigation dripper during the irrigation event is independent of pressure.
6. You can adjust the water usage rate by adjusting the control dripper on the Unpowered Terracotta Valve.
7. You can adjust the interval between irrigation events by adjusting the float on the Unpowered Terracotta Valve.
8. The irrigation system responds automatically to on-site evaporation and rainfall.
9. Simple, unpowered, and low tech, and therefore fewer things can go wrong.
10. Provided that you have a continuous water supply, you can leave your irrigation application unattended for weeks on end.

The irrigation method described in this publication will be referred to as the **Omodei method**.

The Unpowered Terracotta Valve incorporates a small valve with a half inch inlet and outlet. The size of the irrigation zone is limited by the size of the valve. For large irrigation applications, the Terracotta Irrigation Controller for Latching Solenoids should be used.

2. Schematic diagram



3. Installation

Step 1. Arrange laterals so that each lateral follows a different contour level. Use enough laterals so that every plant is at approximately the same level as one of the laterals. The laterals may be NPC dripline or 19 mm polypipe with online NPC drippers. Restrict the length of the laterals so that frictional head loss along the laterals is negligible.

Step 2 (using a header tank). Connect the header tank outlet to the inlet of an Unpowered Terracotta Valve so the gap between the lowest operational water level (in the header tank) and the control dripper is about the same as the gap between the control dripper and the highest lateral. Connect the outlet from the Unpowered Terracotta Valve to a horizontal length of 25 mm polypipe at the same level as the control dripper (this level is called level 0).

Step 2 (using mains pressure). Connect mains pressure water supply to the inlet of an Unpowered Terracotta Valve (for maximum irrigation uniformity the control dripper should be as high as possible). Connect the outlet from the Unpowered Terracotta Valve to a horizontal length of 25 mm polypipe at the same level as the control dripper (this level is called level 0).

Step 3. Let h be the height of the 25 mm polypipe above the highest lateral, let P be the desired irrigation uniformity (95% for example), and let C be the manufacturer's coefficient of variation for the drippers.
Subdivide the slope (or uneven land) into zones as follows:
Zone 1 (Z_1) is from level (–h) to level (-h)* F where $F = 1/(P+C)^2$
Zone 2 (Z_2) is from level (-h)*(1.1) to level (-h)*F^2
Zone 3 (Z_3) is from level (-h)*$(1.1)^2$ to level (-h)*F^3
and so on until all the laterals have been allocated to a zone. If the land is sufficiently level only one zone may be required.

Examples:
If P = 0.95 and C = 0.01 then F = 1.085
If P = 0.95 and C = 0.02 then F = 1.068
If P = 0.90 and C = 0.03 then F = 1.156

Alternative Step 3. To achieve maximum irrigation uniformity, do the planting in rows so that each row (or swale) follows a contour level. The laterals for the zone should be at the same level as the row.

Step 4. For each zone Z_i count the number of irrigation drippers N_i in the zone. Construct a dripper assembly using drippers with the same emitter discharge exponent (see Appendix) as the irrigation drippers. The flow rate of the dripper assembly should be the same as the combined flow rate of the corresponding drippers in the zone. Attach the dripper assembly to the 25 mm polypipe in Step 2 so that all the drippers in the dripper assembly are at level 0.

Step 5. Polypipe can used to deliver water from each dripper assembly to the laterals in the corresponding zone. The diameter of the polypipe will depend on the slope of the land. For example, on steep sloping land 13 mm polypipe can be used. The drippers in the dripper assembly should be open to the atmosphere at all times (in other words, the dripper outlets should be at atmospheric pressure). If water starts overflowing near any of the dripper assemblies, you will need to use an adjustable valve on the inlet side of the Unpowered Terracotta Valve to restrict the flow just enough to stop the overflow.

To minimise frictional head loss along very long laterals you may need to deliver water from the dripper assembly to 3 points on the lateral, namely, at one sixth of the way, at half way, and at five sixths of the way.

Provided that the irrigation system is designed so that frictional head loss along each lateral is negligible, then the desired irrigation uniformity for the entire irrigation system should be achieved. The irrigation uniformity can be further improved by increasing the number of zones.

There is no upper limit on the vertical gap between the dripper assembly and the irrigation drippers (for example, the irrigation drippers may be 50 metres lower than the dripper assembly).

Pressure independent dripper discharge

If you want the water discharged by each irrigation dripper during the irrigation event to be independent of pressure, replace the adjustable control dripper by a control dripper with the same emitter discharge exponent (see Appendix) as the irrigation drippers.

The discharge of the irrigation drippers can be increased by connecting additional terracotta pots to the original terracotta pot so that the water level is the same in all pots. With one additional pot the discharge is slightly more than doubled. With two additional pots the discharge is slightly more than trebled. Continuing in this way the discharge continues to increase.

One way of connecting the pots is to drill a small hole in the bottom of the pots and to use 4 mm rubber grommets, 4 mm barbed elbows and 4 mm tubing. The drain hole in the additional pots should be sealed.

With two additional pots the discharge during the irrigation event is slightly more than trebled.

The pots are connected by 4 mm tubing so that the water level is the same in all the pots.

4. Recommended drippers

All drippers used for the irrigation and the construction of the dripper assembly should have the same emitter discharge exponent (see Appendix).

If you decide to use a combination of drippers for the irrigation application, the following recommendations will assist you in the construction of the dripper assembly.

On line drippers

Netafim NPC button drippers 2 L/H, 4 L/H or 8 L/H (at 100 kPa), emitter discharge exponent 0.480 (available on line from Dural Irrigation)

Dripline

Netafim Aries HWD 13 mm dripline, 0.30 m spacing, emitter discharge exponent 0.46 (available on line from Dural Irrigation)

Netafim Aries HWD 16 mm dripline, 0.30 m spacing, emitter discharge exponent 0.46 (available on line from Land & Water Technology)

To construct the dripper assembly using either of these driplines, it is recommended that 8 L/H dripline is used to reduce the number of drippers needed to construct the dripper assembly.

All of the driplines in the Netafim Aries range have an emitter discharge exponent of 0.46 and so you can choose any Aries dripline for your irrigation application.

For some applications it may be difficult to source suitable drippers that have the same emitter discharge exponent. For example, Antelco Agri Drip Classic 8 L/H drippers have an emitter discharge exponent of 0.47 and the Antelco Agri Drip Classic 2 L/H drippers have an emitter discharge exponent of 0.49 (see Appendix). Suppose that a 2 L/H dripper is used as the control dripper and 8 L/H drippers are used for the irrigation drippers. The following table shows the ratio of the flow rate of the 2 drippers for various values of pressure.

Pressure kPa	Ratio of the flow rate of 8 L/H dripper to the flow rate of the 2 L/H dripper
25	4.34
50	4.29
100	4.23
200	4.17
400	4.12

In general, the ratio of the flow rate of two emitters with different emitter discharge exponents can be calculated by the following formula.

$$\frac{q_2}{q_1} = r\left(\frac{100}{p}\right)^{x_2 - x_1}$$

where q_2 is the flow rate of the high flow emitter at 100 kPa

q_1 is the flow rate of the low flow emitters at 100 kPa

r is the ratio of the high flow rate to the low flow rate at 100 kPa

p is the pressure in kPa

x_2 is the emitter discharge exponent of the high flow emitter

x_1 is the emitter discharge exponent of the low flow emitter

This formula can be used to determine whether the variations in the ratio of the flow rates for different pressures are acceptable.

5. Example

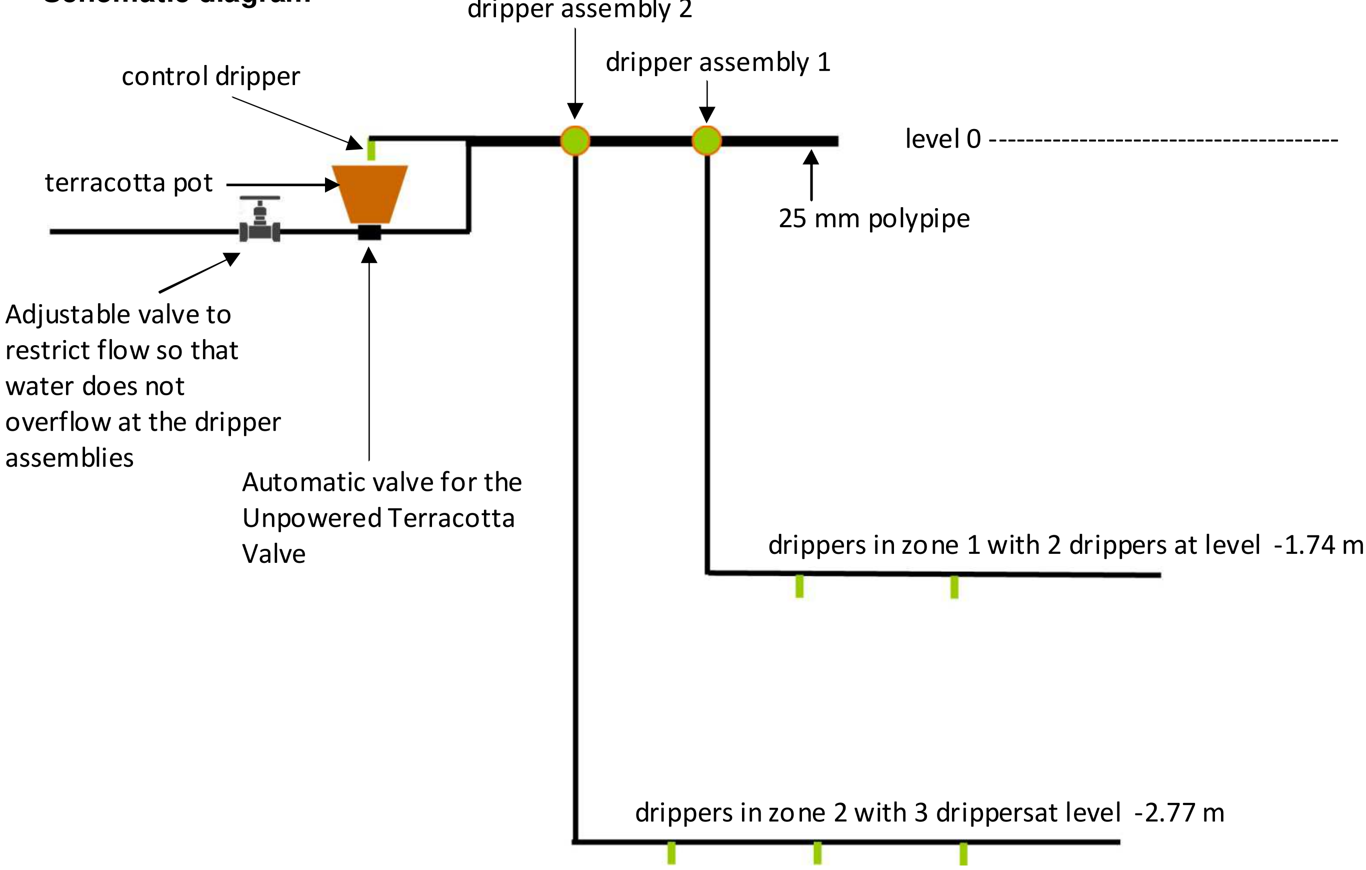
This example is used to obtain some preliminary results to test the following two claims in relation to the Omodei method.

Claim 1. Provided that the irrigation system is designed so that frictional head loss along each - can be achieved.

Claim 2. Provided that the control dripper on the Unpowered Terracotta Valve has the same emitter discharge exponent as the irrigation drippers, the water discharged from each irrigation dripper during the irrigation event is independent of pressure.

The drippers used for this application (including the control dripper) are all Antelco Agri Drip Classic 8 L/H drippers (at 100 kPa). The water supply is from a mains water tap. The control dripper is at level 0, zone 1 has 2 drippers at level -1.74 m, and zone 2 has 3 drippers at level -2.77 m.

Schematic diagram




Zone 1 with 2 drippers at level -1.74 metres.


Zone 2 with 3 drippers at level - 2,77 metres.


Dripper assemblies for zones 1 & 2 at level 0. The drippers are open to the atmosphere.

The Unpowered Terracotta Valve is at the top of the photo with the control dripper at level 0. The green hose delivers water at mains pressure to an adjustable valve connected to the inlet of the Unpowered Terracotta Valve. Polypipe delivers water from the dripper assemblies to the corresponding zones.

Results

	zone 1 dripper 1	zone 1 dripper 2	zone 2 dripper 1	zone 2 dripper 2	zone 2 dripper 3	SD	Mean	Coefficient of Variation	Uniformity
flow rate lph	2.240	2.230	2.210	2.160	2.210	0.0308	2.210	0.0139	0.986
discharge litres	0.307	0.314	0.315	0.326	0.322	0.0074	0.317	0.0233	0.977
pressure metres	0.830		0.750						
flow rate lph	1.642	1.635	1.747	1.785	1.777	0.0733	1.717	0.0427	0.957
discharge litres	0.301	0.303	0.338	0.320	0.314	0.0150	0.315	0.0475	0.953
pressure metres	0.460		0.500						
flow rate lph	1.230	1.267	1.133	1.148	1.288				
discharge litres	0.299	0.306	0.315	0.305	0.321	0.0087	0.309	0.0282	0.972
pressure metres	0.350		0.370						
flow rate lph	0.743	0.768	0.817	0.840	0.855	0.0476	0.805	0.0592	0.941
discharge litres	0.250	0.259	0.277	0.282	0.270	0.0131	0.268	0.0489	0.951
pressure metres	0.125		0.105						
discharge SD	0.026	0.025	0.025	0.020	0.025				
discharge Mean	0.289	0.296	0.311	0.308	0.307				
discharge CV	0.091	0.084	0.081	0.064	0.081				
discharge Uniformity	0.909	0.916	0.919	0.936	0.919				
Discharge statistics when the lowest pressure is excluded									
discharge SD	0.004	0.006	0.013	0.011	0.004				
discharge Mean	0.302	0.308	0.323	0.317	0.319				
discharge CV	0.014	0.018	0.041	0.034	0.014				
discharge Uniformity	0.986	0.982	0.959	0.966	0.986				

The results support both claims.

6. Installation cost

The cost of installing the DIY drip irrigation system on sloping land from a header tank using the Omodei method is a fraction of the cost of installing an equivalent PC system.

- NPC drippers (or dripline) is less expensive than PC drippers (or dripline)
- A header tank does not normally provide enough pressure for PC drippers and so you need to purchase a high pressure pump.
- The pressure requirement for PC drippers means that hose clamps are usually required for barbed connectors. For a header tank and NPC drippers, hose clamps are not needed.
- The range of pressure compensation for a PC system means that many zones are often required. Each zone will require its own solenoid valve and the cost of the solenoid valves is likely to be significant. The DIY system is unpowered and so there are no solenoid valves.
- The PC system requires a conventional irrigation controller and electrical wiring to each of the solenoid valves. The DIY system requires an Unpowered Terracotta Valve and hence no wiring is required.

Appendix Emission discharge exponent

The Netafim Product Catalogue contains the following table for their button drippers.

DRIPPERS TECHNICAL DATA

Button drippers

FLOW RATE* (L/H)	MAXIMUM WORKING PRESSURE (BAR)	WATER PASSAGES DIMENSIONS WIDTH-DEPTH-LENGTH (MM)	CONSTANT K	EXPONENT X	BASIS CODE COLOR	CAP COLOR CODE
2.00	2.0	0.98 x 0.89 x 50	0.662	0.48	Red	Black
3.00	2.0	1.05 x 0.95 x 50	0.993	0.48	Blue	Black
4.00	2.0	1.27 x 1.20 x 50	1.325	0.48	Black	Black
8.00	2.0	1.65 x 1.40 x 50	2.649	0.48	Green	Black

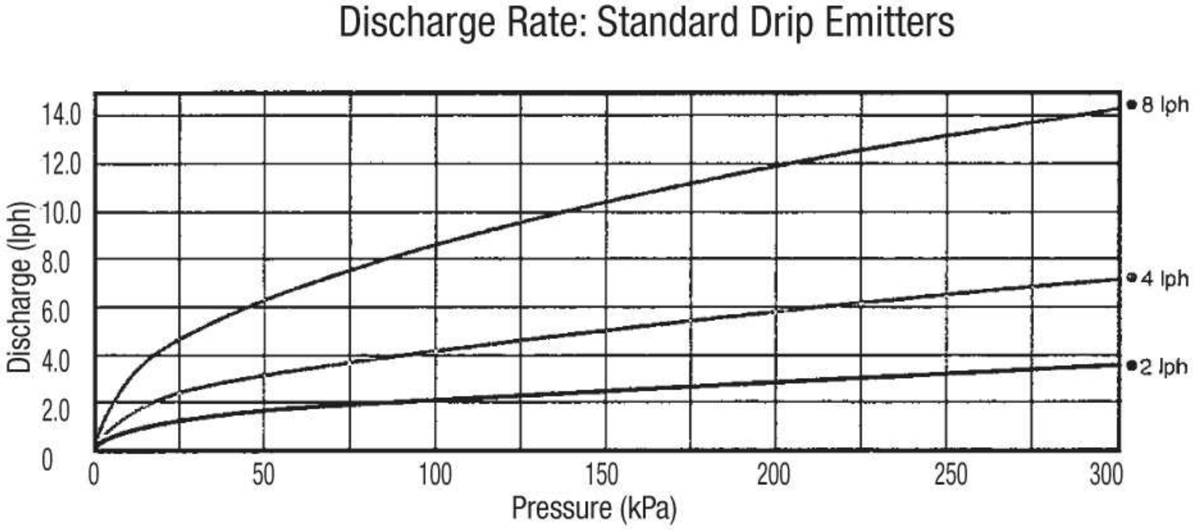
*Flow rate at 1.0 bar pressure

BUTTON DRIPPER
3MM BARB OUTLET

All of the button drippers have an emitter discharge exponent of 0.48.

If these drippers are used, the ratio of the flow rates of any two drippers is independent of pressure.

The Antelco Product Catalogue contains the following flow curve and table for their Agri Drip NPC drippers.



Performance		Standard 2 lph	Standard 4 lph	Standard 8 lph
Discharge (lph)	50 kPa	1.41	2.96	6.07
	75 kPa	1.73	3.58	7.35
	100 kPa	1.99	4.10	8.41
Discharge =	125 kPa	2.22	4.56	9.34
K x Pressure^X	150 kPa	2.42	4.96	10.18
Coefficient of Variation – CV		2.0%	2.0%	2.5%
Constant – K		0.208	0.471	0.966
Exponent – X		0.490	0.470	0.470
Minimum Cross Section (mm)		0.90x0.71	1.28x0.82	1.85x1.09

Agri Drip™ Classic
2 lph

Agri Drip™ Classic
4 lph

Agri Drip™ Classic
8 lph

Note that the red dripper has an emitter discharge exponent of 0.49 and the grey and green drippers have an emitter discharge exponent of 0.47. Therefore, if you use only grey and green drippers, the ratio of the flow rates of any two drippers is independent of pressure.