# Evaluating Pressurization Time and Application Uniformity for Residential Drip Fields

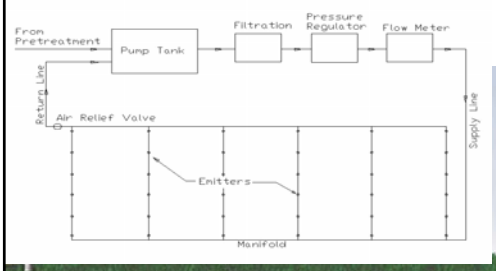
Xiaojing Duan, Bruce Lesikar, Russell Persyn, Ann Kenimer, and Justin Mechell

Texas AgriLife Extension Service

## Overview

- Drip emitters
- Emitter flow rates
- Characterization of emitter flow rates
- Pressure control methods
- Mean pressurization times
- Dose times based on application uniformity

# Subsurface Drip Distribution System







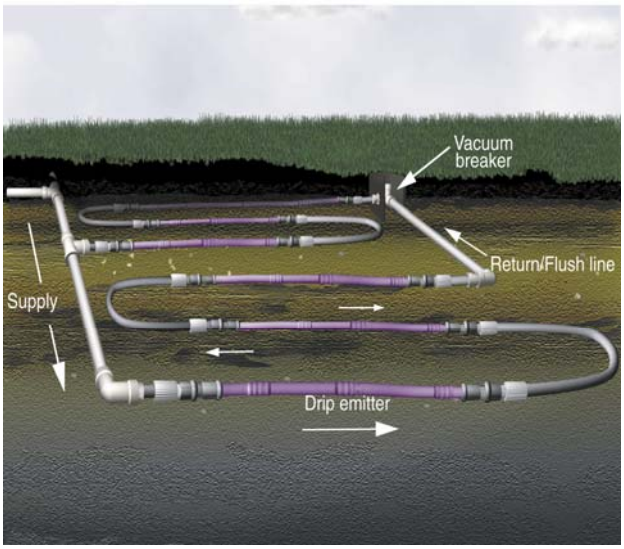
Components:

•Pretreatment
•Pump and pump tanks
•Filtration
•Pressure regulators
•Water distribution devices (flow splitting)
•Drip zone
•Controllers

# Drip Zone

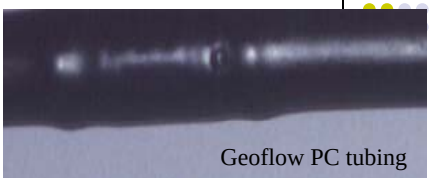
Components:

- Supply line
- Supply manifold
- Drip laterals
- Fittings
- Return manifold
- Return line
- Flush valves
- Air/Vacuum relief valve



# Drip Line

- Drip line approved by the manufacturer for use with wastewater.
- The tubing is generally ½ inch diameter with an emitter equally spaced in the tubing.
- Emitter spacing – 12, 18, 24 inches.
- Bioslime and root intrusion control is achieved by bactericides, herbicides and flushing.



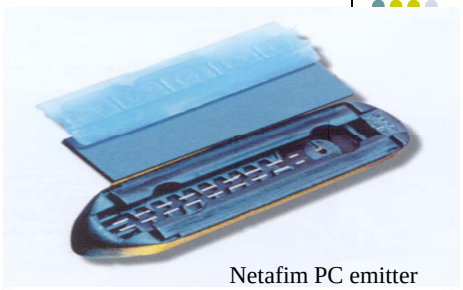
Geoflow PC tubing

Geoflow NPC tubing

Netafim PC tubing

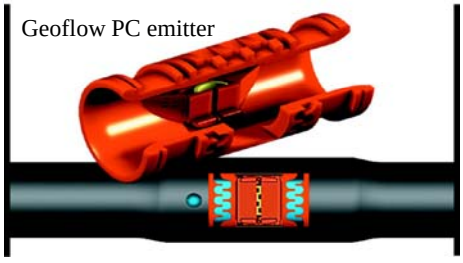
# Drip Emitters

- Emitter types
  - Pressure Compensating
  - Non-Pressure Compensating
- Controlled flow rate for emitters
  - Friction used to control flow
  - 0.43 to 1.15gph
- Operating pressure is typically:
  - 15-25 psi for non-pressure compensating
  - 15-40 psi for pressure compensating emitter systems
  - Water exiting the emitter at 0 psi.

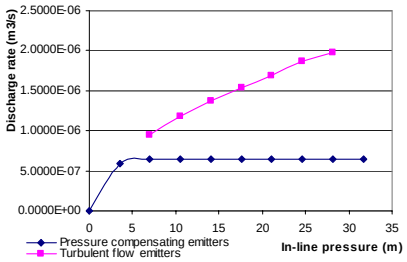


Netafim PC emitter

Geoflow PC emitter



## Wastewater application in drip zone




$$Q = CH^{x}$$

# Dose cycle:

- Pressurization stage – time to reach operating pressure
- Pressurized stage – uniform distribution
- Depressurization stage – control drain down in field
- Resting – water distributes in soil

## Objectives

- Evaluate water emission rates of five types of emitters at 8 pressures ranging from 0 to 310.26 Kpa (45 psi).
- Evaluate and classify the emitter products according to coefficient variation Cv and Christiansen's uniformity coefficient (UC)
- Use statistical methods to evaluate several operational schemes on drip zone with respect to the pressurization stage.
- Evaluate dose time with respect to drip zone design and operational considerations and application uniformity.
- Compare the effects of different system operation pressures and pressure control schemes on dosing time and application uniformity.

## Manufacturer parameters of selected drip tubing

| ** | Tubing Model | Type * | Inside Diameter | Emitter Spacing | Nominal Discharge Rate | Suggested Normal Operation Pressure |
|---|---|---|---|---|---|---|
| 1 | Geoflow WFCL 164-24-500 | NPC | 14 mm (0.55 inch) | 0.61 m (2 feet) | 3.90 liter/hr@137.9 Kpa (1.03 GPH@20 psi) | 68.9-310.3 Kpa (10-45 psi) |
| 2 | Geoflow WFPC 162-24-500 | PC | 14 mm (0.55 inch) | 0.61 m (2 feet) | 2.00 liter/hr@137.9 Kpa (0.53 GPH@20 psi) | 68.9-310.3 Kpa (10-45 psi) |
| 3 | Geoflow WFPC 164-24-500 | PC | 14 mm (0.55 inch) | 0.61 m (2 feet) | 4.00 liter/hr@137.9 Kpa (1.06 GPH@20 psi) | 68.9-310.3 Kpa (10-45 psi) |
| 4 | Netafim Bioline 08WRAM 0.6-24V | PC | 14.5 mm (0.57 inch) | 0.61 m (2 feet) | 2.27 liter/hr@137.9 Kpa (0.6 GPH@20 psi) | 48.3-413.7 Kpa (7-60 psi) |
| 5 | Netafim Bioline 08WRAM 1.0-12500 | PC | 14.5 mm (0.57 inch) | 0.305 m (1 foot) | 3.79 liter/hr@137.9 Kpa (1.0 GPH@ 20 psi) | 48.3-413.7 Kpa (7-60 psi) |

(Netafim, 2004; Geoflow, 2004)

*** NPC = non-pressure compensating; PC = pressure compensating**

****Emitter models 1,2,3,4,5 were tested in lab-scale experiment;**
**Emitter models 1,2,4 were tested in field-scale experiment.**

**Micro-irrigation system uniformity classifications based on manufacturer variance coefficient***

| Emitter type | $C_v$ range | Classification |
|---|---|---|
| Point-source | <0.05 | Excellent |
| | 0.05 – 0.07 | Average |
| | 0.07 – 0.11 | Marginal |
| | 0.11 – 0.15 | Poor |
| | >0.15 | Unacceptable |
| Line-source | <0.10 | Good |
| | 0.10 – 0.20 | Average |
| | >0.20 | Marginal to Unacceptable |

* Adopted from ASABE Standards EP405.1, (2003)

**Micro-irrigation system uniformity classifications based on emitter discharge uniformity****

| Uniformity Coefficient, UC (%) | Classification |
|---|---|
| above 90% | Excellent |
| 90%-80% | Good |
| 80%-70% | Fair |
| 70% -60% | Poor |
| below 60% | Unacceptable |

** Adopted from ASAE Standards EP 458 (1999)

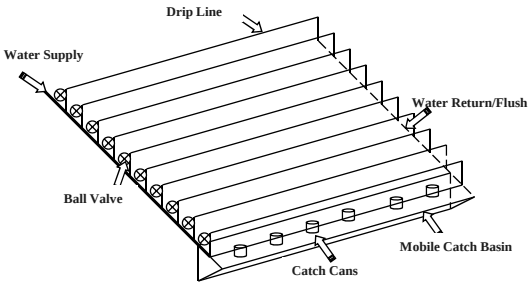
Emitter exponent values for various flow regimes and emitters *

| Flow regime | Exponent x | Emitter type |
|---|---|---|
| Variable flow path | 0.0 | Fully pressure compensating |
| | 0.1 | |
| | 0.2 | |
| | 0.3 | |
| Vortical flow | 0.4 | Partially pressure compensating |
| Fully turbulent flow | 0.5 | Non-pressure compensating |
| Mostly turbulent flow | 0.6 | |
| | 0.7 | |
| Mostly laminar flow | 0.8 | |
| | 0.9 | |
| Fully laminar flow | 1.0 | Fully non-pressure compensating |

* Adapted from IA, 2002

# Methods

## Lab-scale Experiment




**Layout of the test apparatus for emitter evaluation (lab-scale)**

- Sample number: 60
- 8 pressures:
  - 13.79 Kpa/2 psi/1.41 m
  - 27.58 Kpa/4 psi/2.81 m
  - 41.37 Kpa/6 psi/4.22 m
  - 55.16 Kpa/8 psi/5.62 m
  - 68.95 Kpa/10 psi/7.03 m
  - 103.42 Kpa/15 psi/10.54 m
  - 137.90 Kpa/20 psi/14.20 m
  - 310.26 Kpa/45 psi /31.63 m
- Sampling time: 4 mins

## Lab-scale Experiment

Catch-can method

Weighing dry cans before sample event

## Summary of Statistical Analysis on Tested Emitters *

| | Tubing Model | Type** | UC (%) | $C_v$ | DU (%) |
|---|---|---|---|---|---|
| 1 | Geoflow WFCL 164-24-500 | NPC | 95.83 | 0.0528 | 93.32 |
| 2 | Geoflow WFPC 162-24-500 | PC | 94.92 | 0.0670 | 91.49 |
| 3 | Geoflow WFPC 164-24-500 | PC | 92.57 | 0.0873 | 87.79 |
| 4 | Netafim Bioline 08WRAM 0.6-24V | PC | 95.79 | 0.0577 | 94.61 |
| 5 | Netafim Bioline 08WRAM 1.0-12500 | PC | 96.98 | 0.0394 | 95.73 |

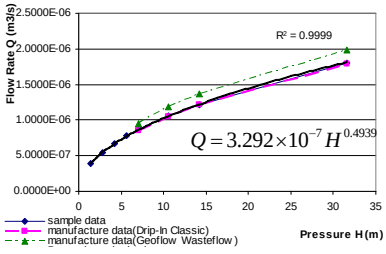
* Note: Mean values under eight pressures between 0 and 31.65 m (45psi)
** NPC = non-pressure compensating; PC = pressure compensating

## Micro-irrigation system classifications of tested emitters based on uniformity coefficient (UC) * and manufacturer's coefficient of variation ($C_v$) **

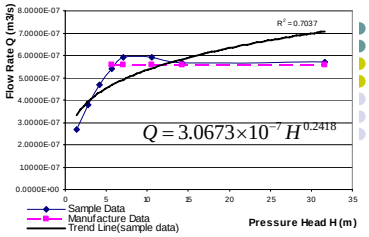
| | Classification factors and results | Geoflow WFCL 164-24-500 | Geoflow WFPC 162-24-500 | Geoflow WFPC 164-24-500 | Netafim Bioline 08WRAM 0.6-24V | Netafim Bioline 08WRAM 1.0-12500 |
|---|---|---|---|---|---|---|
| 1 | UC (%) | 95.83 | 94.92 | 92.57 | 95.79 | 96.98 |
| | Classification | Excellent | Excellent | Excellent | Excellent | Excellent |
| 2 | $C_v$ | 0.0528 | 0.0670 | 0.0873 | 0.0394 | 0.0577 |
| | Classification | Average | Average | Marginal | Excellent | Average |

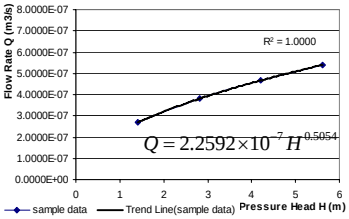
* Adopted from ASAE Standards EP 458 (1999).
** Adopted from ASABE Standards EP405.1 (2003).

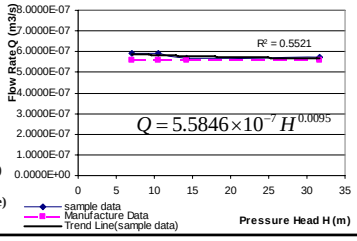
## Characterization of flow rate and pressure head relationship (Q-H Curve) of emitters




Q-H curve of Geoflow WFCL 164-24-500 (0-31.63 m/45 psi)




Q-H curve of Geoflow WFPC 162-24-500 (0-31.63 m/45 psi)
Q-H curve of Geoflow WFPC 162-24-500 (Low Pressure)
Q-H curve of Geoflow WFPC 162-24-500 (Normal Pressure)

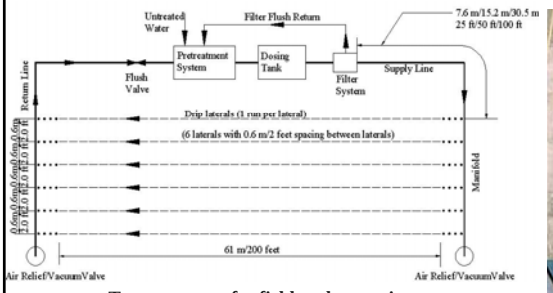
## Summary of Q-H Curve *

| | Whole pressure range (0-31.63 m/45 psi) | Low pressure range | Normal pressure range |
|---|---|---|---|
| **Geoflow WFCL 164-24-500** | $Q = 3.292\times10^{-7} H^{0.4939}$ | ------ | ------ |
| **Geoflow WFPC 162-24-500** | $Q = 3.0673\times10^{-7} H^{0.2418}$ | $Q = 2.2592\times10^{-7} H^{0.5054}$ | $Q = 5.5846\times10^{-7} H^{0.0095}$ |
| **Geoflow WFPC 164-24-500** | $Q = 4.035\times10^{-7} H^{0.322}$ | $Q = 3.1631\times10^{-7} H^{0.5224}$ | $Q = 7.985\times10^{-7} H^{0.0659}$ |
| **Netafim Bioline 08WRAM 0.6-24V** | $Q = 5.9535\times10^{-7} H^{0.0599}$ | $Q = 4.7153\times10^{-7} H^{0.3033}$ | $Q = 7.985\times10^{-7} H^{0.0659}$ |
| **Netafim Bioline 08WRAM 1.0-12500** | $Q = 8.3687\times10^{-7} H^{0.0670}$ | $Q = 6.8646\times10^{-7} H^{0.2831}$ | $Q = 9.6975\times10^{-7} H^{0.0052}$ |

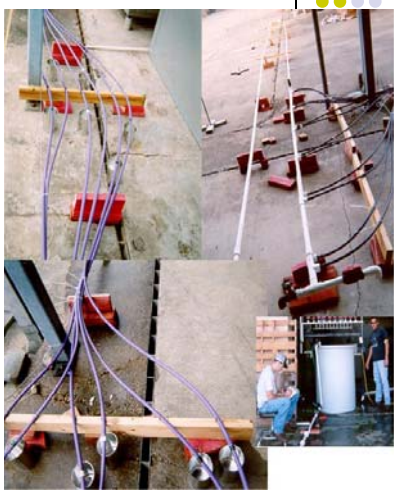
* For Geoflow products, the low pressure range is from 0 to 68.95 Kpa (7.03 m/10 psi); the suggested normal pressure range is 68.95-310.26 Kpa (7.03-31.63 m)/(10-45 psi).
For Netafim products, the low pressure range is from 0 to 48.26 Kpa (4.92 m/7 psi); the suggested normal pressure range is 48.26-413.69 Kpa (4.92-42.61 m)/(7-60 psi).

# Methods

## Field-scale Experiment




**Test apparatus for field-scale experiment**



Lateral length of NPC tubing: 61 m/200 ft
Lateral length of PC tubing: 122 m/400 ft


L - Lateral Length

**Emitter sample distribution**

**Three factors concerning the drip zone design in the residential, single family wastewater project**

- **Supply line length**:
  7.6 m or 15.2 m or 30.5 m (25 ft/50 ft/100 ft)
- **System operational pressure groups**: 14.1 m (137.8 Kpa/20 psi) or 28.1 m (275.8 Kpa/40 psi)
- **Operational pressure control schemes**:
  - Bypass flow; intermittent flushing
  - Pressure regulator; intermittent flushing
  - Flow restriction (gate valve on the return line); continuous flushing

**Pressure control parts/components:**

- Recirculation valve
- Pressure regulator installed in the supply line
- Gate/globe valve

| Scen | Pressure Control | Geoflow WFCL 164 | Geoflow WFPC 162 | Netafim WRAM 0.6 |
|---|---|---|---|---|
| 1 | 20 psi Pres Reg & Int. flushing | Y | Y | Y |
| 2 | Bypass & Int Flush & 20 psi | Y | Y | Y |
| 3 | Cont. Flush & Gate Ret.& 20psi | Y | N | N |
| 4 | Bypass & Int Flush & 40 psi | N | Y | Y |
| 5 | Cont. Flush & Gate Ret.& 40psi | N | Y | Y |
| 6 | 45 psi Pres Reg & Int. flushing | N | Y | Y |

## Geoflow WFCL 164-24-500

1. Descriptive and Tukey HSD test on drip zone pressurization time (seconds) *

| Different scenarios ** | N | Mean pressurization time (s) | Std. deviation | 95% Confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| Scenario 1 a | 9 | 67.56 | 6.29 | 62.72 | 72.39 |
| Scenario 2 b | 9 | 87.33 | 7.42 | 81.63 | 93.03 |
| Scenario 3 a | 9 | 63.44 | 5.66 | 59.09 | 67.79 |

* Means for groups in homogeneous subsets (a, b) were displayed. Mean difference significance = 0.05

**Bypass flow increased time to reach pressure**

## Geoflow WFPC 162-24-500

1. Descriptive and Tukey HSD test on drip zone pressurization time (seconds) *

| Different scenarios | N | Mean emission time (s) | Std. deviation | 95% Confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| Scenario 1 c | 9 | 178.56 | 3.13 | 176.15 | 180.96 |
| Scenario 2 d | 9 | 197.89 | 9.31 | 190.74 | 205.04 |
| Scenario 4 c | 9 | 180.56 | 9.28 | 173.43 | 187.69 |
| Scenario 5 a | 9 | 125.78 | 6.36 | 120.89 | 130.67 |
| Scenario 6 b | 9 | 144.00 | 7.26 | 138.42 | 149.58 |
| | 45 | 165.36 | 27.60 | 157.06 | 173.66 |

* Means for groups in homogeneous subsets (a, b, c, d) were displayed. Mean difference significance = 0.05

2. Two Independent-sample T test on drip zone operation pressures

| T-test for equality of means (seconds) | | | | | |
|---|---|---|---|---|---|
| t | Sig. (2-tailed) | Mean difference of emission time (s) | Std. error difference | 95% Confidence interval of the difference | |
| 6.140 | 0.001 | 38.11 | 6.21 | 25.59 | 50.63 |

3. For Geoflow PC and NPC products, pressure control scheme has the greatest effect on drip system application uniformity, but system operational pressure also impacts AU.

**Bypass flow increased time to reach pressure**

## Netafim Bioline 08WRAM0.6-24V

1. Descriptive and Tukey HSD test on drip zone pressurization time (seconds) *

| Different scenarios | N | Mean emission time (s) | Std. deviation | 95% Confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| Scenario 1 a | 9 | 137.00 | 4.64 | 133.44 | 140.56 |
| Scenario 2 a | 9 | 181.89 | 4.26 | 178.62 | 185.16 |
| Scenario 4 a | 9 | 153.44 | 13.40 | 143.12 | 163.77 |
| Scenario 5 a | 9 | 120.78 | 3.87 | 117.81 | 123.75 |
| Scenario 6 b | 9 | 275.89 | 90.30 | 206.49 | 345.29 |

* Means for groups in homogeneous subsets (a, b) were displayed. Mean difference significance = 0.05.

2. Two Independent-sample T test on drip zone operation pressures

| T-test for equality of means (seconds) | | | | | |
|---|---|---|---|---|---|
| t | Sig. (2-tailed) | Mean difference of emission time (s) | Std. error difference | 95% Confidence interval of the difference | |
| 0.024 | 0.981 | 1.84 | 76.07 | -150.27 | 153.96 |

3. For Netafim PC tubing, pressure control scheme has the greatest effect on drip system application uniformity. Operational pressure does not have serious influence on AU.

**Bypass flow increased time to reach pressure**

## Netafim Bioline 08WRAM0.6-24V

1. Descriptive and Tukey HSD test on drip zone pressurization time (seconds) *

| Different scenarios | N | Mean emission time (s) | Std. deviation | 95% Confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| Scenario 7 | 9 | 618.56 | 32.30 | 593.75 | 643.36 |
| Scenario 8 | 9 | 692.44 | 528.00 | 286.83 | 1098.10 |

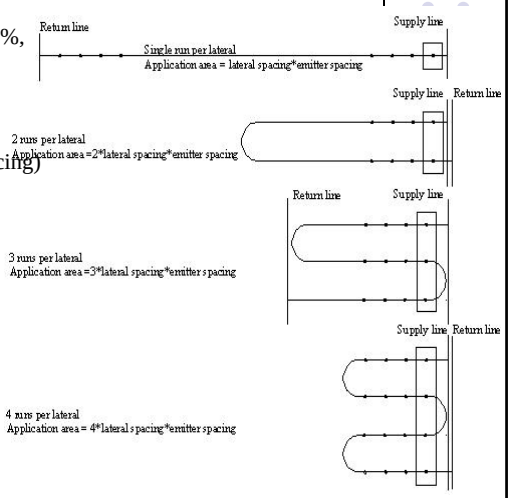
| Pressure control scheme and pressure | Netafim Bioline 08WRAM 0.6-24V |
|---|---|
| Flow restriction (gate valve on supply line) & intermittent flushing & 137.9 Kpa (20 psi) end pressure | Scenario 7 |
| Flow restriction (gate valve on supply line) & intermittent flushing & 275.8 Kpa (40 psi) end pressure | Scenario 8 |

**No supply line valve**

## Drip Zone Dose Time Calculation

- Dose time was computed and reported under expected Application Uniformity (AU) of 85%, 90%, 95%
- Associated application area (runs per lateral × lateral spacing × emitter spacing)
- Calculation Process:
  - Pressurization stage
  - Pressurized stage
    $\Delta V_1 = V_{inlet1} - V_{end1}$
  - Total
    $\Delta Q_2 = Q_{inlet2} - Q_{end2} \quad \Delta V_2 = \Delta Q_2 * T_2$

$$1 - \frac{(\Delta V_1 + \Delta V_2)}{V_{avg}} \geq X\% \qquad T = T_1 + T_2$$




## Drip zone dose time for Geoflow WFCL 164-24-500 (minutes)

| Lateral layout | | Single run lateral | | | Looped lateral (2 runs) | | | Looped lateral (3 runs) | | | Looped lateral (4 runs) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Application Uniformity (AU) | | 85% | 90% | 95% | 85% | 90% | 95% | 85% | 90% | 95% | 85% | 90% | 95% |
| Scenario 1 | 20 psi pressure regulator & intermittent flushing | 53 | ------ | ------ | 2 | 2 | 2 98.3% | 2 | 2 | 3 | 2 | 2 | 2 100% |
| Scenario 2 | Recirculation valve (bypass flow) & intermittent flushing & 20 psi inlet pressure | 52 | ------ | ------ | 2 | 2 | 2 97.3% | 2 | 2 | 3 | 2 | 2 | 2 100% |
| Scenario 3 | Flow restriction (gate valve on return line) & continuous flushing & 20 psi end pressure | 55 | ------ | ------ | 2 | 2 | 2 99.0% | 1 | 2 | 4 | 2 | 2 | 2 100% |

## Drip zone dosing time for Geoflow WFPC 162-24-500 (minutes)

| Lateral layout | | Single run lateral | | | Looped lateral (2 runs) | | | Looped lateral (3 runs) | | | Looped lateral (4 runs) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Application Uniformity (AU) | | 85% | 90% | 95% | 85% | 90% | 95% | 85% | 90% | 95% | 85% | 90% | 95% |
| Scenario 1 | 20 psi pressure regulator & intermittent flushing | 22 | 33 | 70 | 3 | 3 | 3 100% | 4 | 5 | 8 | 3 | 3 | 3 100% |
| Scenario 2 | Recirculation valve (bypass flow) & intermittent flushing & 20 psi inlet pressure | 28 | 36 | 76 | 4 | 4 | 4 100% | 4 | 6 | 9 | 4 | 4 | 4 100% |
| Scenario 4 | Recirculation valve (bypass flow) & intermittent flushing & 40 psi inlet pressure | 13 | 19 | 38 | 3 | 3 | 3 100% | 3 86.9% | 4 | 5 | 3 | 3 | 3 100% |
| Scenario 5 | Flow restriction (gate valve on return line) & continuous flushing & 40 psi end pressure | 16 | 20 | 47 | 3 | 3 | 3 100% | 2 88.2% | 3 | 5 | 3 | 3 | 3 100% |
| Scenario 6 | 45 psi pressure regulator & intermittent flushing | 13 | 19 | 38 | 3 | 3 | 3 100% | 3 88.2% | 3 | 5 | 3 | 3 | 3 100% |

## Drip zone dosing time for Netafim Bioline 08WRAM0.6-24V (minutes)

| Lateral layout | | Single run lateral | | | Looped lateral (2 runs) | | | Looped lateral (3 runs) | | | Looped lateral (4 runs) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Application Uniformity (AU) | | 85% | 90% | 95% | 85% | 90% | 95% | 85% | 90% | 95% | 85% | 90% | 95% |
| Scenario 1 | 20 psi pressure regulator & intermittent flushing | 14 | 22 | 50 | 3 | 3 | 3 100% | 3 | 3 | 5 | 3 | 3 | 3 100% |
| Scenario 2 | Recirculation valve (bypass flow) & intermittent flushing & 20 psi inlet pressure | 17 | 27 | 78 | 4 | 4 | 4 100% | 4 | 4 | 6 | 4 | 4 | 4 100% |
| Scenario 4 | Recirculation valve (bypass flow) & intermittent flushing & 40 psi inlet pressure | 13 | 18 | 36 | 3 | 3 | 3 100% | 3 | 3 | 6 | 3 | 3 | 3 100% |
| Scenario 5 | Flow restriction (gate valve on return line) & continuous flushing & 40 psi end pressure | 9 | 13 | 26 | 4 | 4 | 4 100% | 4 | 4 | 5 | 4 | 4 | 4 100% |
| Scenario 6 | 45 psi pressure regulator & intermittent flushing | 8 | 12 | 22 | 5 | 5 | 5 100% | 5 | 5 | 5 97.4% | 5 | 5 | 5 100% |

## Conclusions

### Field-scale Experiment

- The pressurization stage is crucial concerning the drip zone application uniformity.
- Among three factors : drip zone operational pressures, different drip zone pressure control schemes and supply line lengths, the residential supply line and manifold lengths do not severely affect dose time and dose volume.
- Looped lateral with several runs is a valuable method to help improve the water application uniformity and to shorten the required dose time.