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# Effect of manifold layout and fertilizer solution concentration on fertilization and flushing times and uniformity of drip irrigation systems

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A R T I C L E I N F O

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A B S T R A C T

Applying fertilizer through drip irrigation system is a very important method to save fertilizer and labour. Three manifold layouts (water supply in one end for transversal drip tapes (M1), water supply in both ends for transversal drip tapes (M2) and water supply in one end for longitudinal drip tapes (M3)) and four different fertilizer solution concentrations (50.00 g $L^{-1}$ (C1), 66.67 g $L^{-1}$ (C2), 100 g $L^{-1}$ (C3) and 200 g $L^{-1}$ (C4)) were selected to investigated the effect of the manifold and concentration on water fertigation uniformity. Results showed that the emitter at the extreme end of the manifold needed more time to clean the rudimental fertilizer in the drip tapes. The minimal flushing time increased from 8 to 13, 4 to 7 and 7 to 12 min with increasing the fertilizer concentration from C1 to C4 for M1, M2 and M3, respectively. The drip irrigation system needed more time for flushing to reduce the risk of emitter clogging when a higher fertilizer solution concentration was applied. In order of performance, M2 had the highest water and fertilizer uniformity, followed by M3 and lastly by M1. The fertilizer solution concentration had no significant effect on water distribution. However, it had a significant effect on fertilizer distribution. The mass of the applied fertilizer for the drip tapes close to the inlet increased with increasing fertilizer solution concentration from C1 to C4, which indicated that higher fertilizer solution concentration can result in lower fertilizer distribution uniformity. There was a significant effect of the manifold layout on water uniformity. The fertilizer concentration and the interaction between manifold layout and concentration had no significant effect on the water uniformity. Similarly, both the manifold layout and concentration had a significant effect on fertilizer uniformity. The interaction between manifold layout and concentration had a significant effect on the Christiansen's uniformity (CU) and distribution uniformity (DU) for fertilizer, whilst, a significant effect on emission uniformity (EU) was not found. The manifold layout and fertilizer solution concentration should therefore be considered in the design and operation of fertigation system.

## 1. Introduction

Drip irrigation has the potential to offer a precise, flexible and high level irrigation management method (Demir et al., 2007; Ella et al., 2009; Yurdem et al., 2015). It can be adapted to different cropping patterns and climates. Fertigation is the application of fertilizer to a crop through an irrigation system (Bar-Yosef, 1999). Watts and Martin (1981) showed that fertigation has several advantages over conventional blended fertilizer such as lower fertilizer inputs, reduced nutrient leaching, flexibility in scheduling to meet crop demands and lower costs. Lamm et al. (2001) stated that accurate application of nitrogen through drip irrigation can enhance crop yields and reduce the potential for groundwater contamination from nitrates. Fertigation is expected to play a major role in the future to efficiently meet demands of fertilizer and minimise environmental consequences of irrigation (Brahma et al., 2010; Kumari and Kaushal, 2014; Li et al., 2016). However, several factors such as injector type, manifold layout, and fertilizer solution concentration can potentially affect the water and fertilizer uniformity of the drip fertigation system.

The effect of injector type on fertigation uniformity has already been widely investigated. Bracy et al. (2003) obtained better fertilizer distribution uniformity with the proportional injector compared with the continuously diluting injector in a greenhouse experiment. Li et al. (2007) evaluated the effects of different injector types on the fertigation uniformity of subsurface drip irrigation systems, and the proportional injector was recommended for the design of fertigation system. Fan et al. (2016) assessed the proportional injector, differential pressure tank and Venturi injector, and indicated that the proportional injector resulted better fertilizer uniformity. Hence, the proportional injector is generally preferred for most fertigation applications due to its high

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accuracy in metering fertilizer into the system (Bracy et al., 2003; Han et al., 2010; Li et al., 2016).

Moreover, the injector type, manifold layout and fertilizer solution concentration are additional factors that affect the water and fertilizer uniformity of drip irrigation systems. Sun (2014) compared the water uniformity of longitudinal and transverse lateral layouts in the greenhouse, and reported that the water uniformity of the transverse lateral layout was greater than that of the longitudinal arrangement due to the larger pressure head losses from the longer lateral length. Bomfim et al. (2014) evaluated the uniformity of potassium distribution for a drip irrigation system and indicated that the potassium concentration decreased linearly with increasing distance between injection point and drip tape inlet. Fan et al. (2016) also evaluated the effect of differential pressures and piping arrangements on fertigation uniformity through field experiments, and indicated that the water distribution uniformity was higher than the fertilizer distribution uniformity for water supply from one end and from the middle longitudinally. Some researchers also have focused on fertilizer solution concentration. Nemali and van Iersel (2004) evaluated the effects of photosynthetic photon flux, fertilizer concentrations and the interaction on growth rate. Dong et al. (2006) studied the nitrate nitrogen concentration distribution characteristics under single point source infiltration with different fertilizer solution concentrations based on an indoor experiment. Kumar et al. (2012) evaluated the injection rate of a commercially available Venturi injector under different differential pressure and fertilizer solution concentration.

Few studies have been carried out to evaluate the influence of manifold layout and fertilizer solution concentration on fertigation distribution uniformity of drip irrigation system. Hence, the specific objectives of this research were to evaluate the effect of manifold layout, concentration and their interaction on fertigation uniformity, and provide the design and manage basis for a drip irrigation system.

## 2. Materials and methods

### 2.1. Fertilizer injection device

Fig. 1 shows a schematic diagram of the proportional injector, which was installed directly in the water supply line. The pump operates without the electrical motor. It uses the flow of water as the power source to activate the motor piston, which takes up the required percentage of concentrate and injects it into the water. Inside the pump,

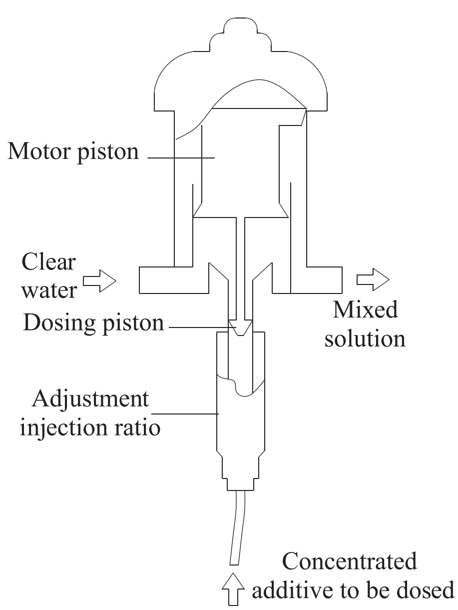


**Fig. 1.** Schematic diagram of proportional injector.

**Table 1**
Different treatments of fertilizer solution concentration.

| Fertilizer treatment | Fertilizer (kg) | Fertilizer solution volume (L) | Concentration ($g\,L^{-1}$) |
|---|---|---|---|
| C1 | 1 | 20 | 50.00 |
| C2 | 1 | 15 | 66.67 |
| C3 | 1 | 10 | 100.00 |
| C4 | 1 | 5 | 200.00 |

the injected solution is mixed with the water and the water pressure forces the mixed solution downstream. The setting injection ratio can be adjusted by changing the dosing piston stroke in the piston chamber. The D25RE2 proportional injector from the Dosatron International S.A.S. Rue Pascal, France was selected for this study. Table 1 presents the technical parameters of the proportional injector. The inlet and outlet inside diameter were 19 mm, the working pressure ranged from 0.02 to 0.6 MPa and the setting injection ratio ranged from 0.2% to 2.0%.

### 2.2. Performance testing for emitter

The drip tapes with internally embedded sticking patch emitters (Shanghai Huawei Water Saving Irrigation Corp., Ltd, China) were used as laterals, which have a nominal diameter of 16 mm, a wall thickness of 0.6 mm, an emitter spacing of 30 cm, a nominal flow rate of 2.7 $L\,h^{-1}$ with an operating pressure of 100 kPa. Fig. 2 shows detail of the performance testing for emitter. Five lateral lines were used in the test and each one with five emitters.

The manufacturing variability of emitter flow rate variation coefficient ($C_V$) was one important index to evaluate the hydraulic performance of emitter, which can be calculated by the following equation:

$$C_V = \frac{S}{q_{ave}} \times 100\% \tag{1}$$

where $C_V$ is the manufacturing variability of emitter flow rate variation coefficient (dimensionless); dimensionless $S$ is the standard deviation of the emitter flow rate of the sample and $q_{ave}$ is the emitter average flow rate of the sample.

### 2.3. Field experiments

Field experiments were conducted to investigate the effect of different manifold layouts and different solution concentrations on fertilization time and fertigation uniformity for the drip irrigation system. Based on the most common glasshouse size in China, an identical area with the length and width of 40 m × 7 m was chosen as the test field. Three manifold layouts (shown in Fig. 3) were investigated in this study, namely, water supply in one end for transversal drip tapes (M1), water supply in both ends for transversal drip tapes (M2), water supply in one end for longitudinal drip tapes (M3), respectively. For M1 and M2, seven 40 m long drip tapes with 1 m spacing between the drip tapes were installed in the field. However, the drip tapes were interrupted in the middle in order to ease flushing for M2. For M3, 40 7-m-long drip tapes with 1 m spacing between the drip tapes were installed in the field. A total of 40 points on the drip tapes were sampled to investigate the fertigation uniformity according to the ASAE standard EP458 (ASAE, 2003). For M1 and M2 (shown in Fig. 3a and b), four drip tapes were selected and each one had 10 sampled points with the spacing of 4 m wide to ensure better representation and consistency. For M3 (shown in Fig. 3c), ten drip tapes were selected and each one had four sampled points with the spacing of 1.5 m wide. To investigate the fertilizer travel time in drip irrigation system, M1, M2 and M3 had four additional sampled points to monitor the variation of fertilizer solution concentration. The concentration of each additional sampled point was measured every minute when the fertilizer solution began to inject into