Efficiency of Triple Emitter Source (TES) for Irrigation Experiments of Horticultural Crops

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Abstract

Triple emitter source TES experimental irrigation was designed. Three trickle laterals were connected together in order to form a triple joint lateral. Two of them and their emitters are connected to two tanks of stock solutions. The third lateral contains only fresh water. The emitters of the two solution lines have different and varying discharges to obtain several mixings of the two stock solutions. The third line is necessary to obtain constant water application rates for each trickling point along the lateral. This method was tested for several experiments involving the study of the combined effects of salinity and fertilizers on the yield function of horticultural crops, namely lettuce and cabbage. As concluding remarks, it was shown the high uniformity of the factor to be evaluated, through the use of Christiansen coefficient of uniformity distribution CUC, which value was always larger than 90%. Main advantage of this experimental design is its smaller experimental plots (reducing pollution and research costs).

INTRODUCTION

In order to estimate horticultural production functions, two major methodologies are being used in experimental designs. One of them - multifactorial experiments, which is the most common and conventional experimental design, like the randomized blocks. These experiments require complex designs and large areas, becoming too expensive. The introduction of the gradient experiments for sprinkle (Fox, 1973) and trickle irrigation (de Mallach et al., 1996) experiments (including fertigation, pestigation, wastewater reuse and recycling, plant water relations). These new experimental designs are much less expensive and a much higher number of irrigation treatments can be obtained. (Beltrão, 1999). These new experiments based on the concept of spatial variable experiments, introduced by Fox (1973) were applied to sprinkle irrigation (line source and point source experiments) and trickle irrigation experiments. Firstly, it was developed single sprinkle line source (Hanks et al., 1976), and after was developed the multiple sprinkle line sources, like the triple line (Lauer, 1983); the linear irrigation gradient was created from a sprinkle point source by Hartmann and Zengerle (1985) and was later developed by Or and Hanks (1992). However, these experiments were very limited, once that they were basically limited to one variable. In order to use two variables instead of one it was created the sprinkle crossed triple line experiment (Magnusson et al., 1989; Magnusson and Ben Asher, 1990). Because there are several disadvantages of the sprinkle spatial variable experiments, namely the requirement of large borders for the plots and problem with the wind, in order to combat these inconvenient, de Mallach et al. (1996) developed the trickle irrigation design known by double emitter source DES, where the double line concept was applied to trickle irrigation. The present work has the objective of application of the triple line source concept to trickle irrigation.

MATERIALS AND METHODS

Description of the Triple Emitter Source

An experimental plot was established in the Campus of Gambelas of the University of Algarve, Faro, South Portugal, according to Figures 1 and 2. Trickle irrigation and triple emitter source TES was used for water application, allowing a gradient of a trickle irrigation applied salt (NaCl) and nitrogen (NH_4NO_3). All the emitters were self compensating emitters. One salt trickle line and its emitters were connected to a tank of NaCl solution. One nitrogen trickle line and its emitters were connected to a tank of NH_4NO_3 solution. These two trickle lines were coupled together with a fresh water trickle line to form a triple-joint. The emitters of the three laterals have different and varying discharges to obtain various mixings between the three lines while maintaining constant application rates for each dripping point. The space between trickle points along the lateral and between sets of three lines was 1m. However the varying discharges of the emitters provokes varying salt and N concentrations of each dripping point along the lateral, and the darkness represents increasing salinity (Fig. 1). Layout of the triple emitter source TES design. S, N and F lines represent the salt, fertilizer and fresh water trickle lines, respectively.

Maximal concentrations of NaCl and NH_4NO_3 were, respectively, 7 (ECw = 10.98 dS m^{-1}) and 2 g L^{-1}. The discharge of each trickle point Q_i, at the *i*th location of each dripping point (where i = 1 to n), is constant and given by

$$Q_i = qS_i + qN_i + qF_i = \qquad (1)$$

where qS_i, qN_i and qF_i are the discharges of the emitter of each single line, respecively, the salt line, the nitrogen line and the fresh water line, at the *i*th location of the trickle point. The masses of each solute MS_i (NaCl) and MN_i (NH_4NO_3) applied at each *i*th location of the dripping point is

$$MS_i = qS_i \text{ x } CS_i \qquad (2a)$$
$$MNi = qN_i \text{ x } CN_i \qquad (2b)$$

where CS_i and CN_i are, respectively, the NaCl and NH4NO3 weighted concentrations, at the dripping point i , which are obtained as

$$<CS_i> = MS_i / Q_i \qquad (3a)$$
$$<CN_i> = MN_i / Q_i \qquad (3b)$$

Some Additional Modifications

1. The Application of an Additional Line to a Double Emitter Source. This trickle irrigation system can work as a normal double emitter source system and also as triple emitter source. It can be interesting, if there was already a DES layout and there is a need also to apply a TES experiment. On this case, for each N or S treatment, there will be different discharges, according to the different amounts of the new studied variable. There was a DES salinity experiment in the Campus of Gambelas, where each salt trickle lateral and its emitter was connected to a tank of salt solution which was coupled to a fresh trickle lateral to form a double joint lateral (Beltrão et al., 2000 a). The emitters of the two laterals had different and varying discharges to obtain various mixing between the two lines while maintaining constant application rates for each dripping point. One trickle fertilizer line and its emitters was connected to a tank of fertilizer solution which was coupled to the double joint lateral in order to form a triple joint lateral. The self compensating emitters of each trickle fertilizer line had constant discharges, but the trickle fertilizer lines had different discharges, according to the different fertilizer amounts of the fertilizer treatments. The space between trickle points along the lateral and between sets of three lines was 1m. However the varying discharges of the emitters provokes varying salt and N concentrations of each trickling point along the lateral. The discharge of each dripping point Q_i, at the same *i*th location of each dripping point (where i = 1 to n) is constant and it is given by eq. 1. The discharge of each dripping point Qj at each different location of the *k*th triple joint lateral (where j,k = 1 to n); its value is not constant, it depends on the different fertilizer amount of the fertilizer treatment; it is given by

$$Qj,k = qS_{j,k} + qN_{j,k} + qF_{j,k} \quad (4)$$

where $qS_{j,k}$, $qN_{j,k}$ and $qF_{j,k}$ are the discharges of the emitter of each single triple point line, respectively, the salt line, the nitrogen line and the fresh water line, at the *j*th triple dripping point, located at the *k*th triple joint lateral.

The masses of each solute $MS_{j,k}$ (NaCl)and $MNjk$ (NH_4NO_3) applied at each *j*th dripping point, located the at *k*th different triple joint lateral is

$$MS_{j,k} = qS_{j,k} \text{ x } CS_{j,k} \quad (5a)$$
$$MN_{j,k} = qN_{j,k} \text{ x } CN_{j,k} \quad (5b)$$

where $CS_{j,k}$ and $CN_{j,k}$ are, respectively, the NaCl and NH4NO3 weighted concentrations, at each *j*th dripping point located at the *k*th triple joint lateral , which are obtained as

$$<CS_{j,k}> = MS_{j,k} / Q_{j,k} \quad (6a)$$
$$<CN_{j,k}> = MN_{j,k} / Q_{j,k} \quad (6b)$$

This layout can be used as a double emitter source DES (if there are only the two laterals discharging each one different and varying amounts to obtain various mixing between the two lines while maintaining constant application) or as a triple emitter source (adding the trickle fertilizer line and its emitters, connected to a tank of fertilizer solution which was coupled to the double joint lateral in order to form a triple joint lateral).

Decrease of the Lack of Randomization

Triple emitter source TES allows randomized layouts, because the triple dripping points may have a random arrangement, by changing the locations of the triple dripping points.

RESULTS

This experimental design was applied to the study of the combined effects of salts and nitrogen on the yield function of lettuce (Beltrão et al., 2000 b) and on the yield of cabbage (Silva, 2000). In order to be appreciated the efficiency of the system, it is shown in table 1 the uniformity of water distribution and of salt (NaCl), through the Coefficient of Christiansen CUC (1942). All parameters were found to be significant at 0.05.level (Cerca, 2000). Because of lack of randomization the normal analysis of variance ANOVA could not be used to evaluate significance.

The average determination coefficient R^2 obtained for yield functions were for the salt regression equations 0.90 (with a maximal deviation of 0.29) and 0.70 (with a maximal deviation of 0.26).

CONCLUSIONS

The above results show that triple emitter source experiments can be used for precise application of varying salinity (NaCl) or nitrogen (NH_4NO_3) concentrations.

Modifications to the first described TES layout were described above. Both of them are more complex, but the first one has the advantage of the use also as a double emitter source DES. The second one has the advantage of allowing randomized layout, by changing at random the position of the triple trickle points. The lack of randomization can be also decreased, through the application of geostatistics (Ben Asher, 1983).

As concluding remarks, it may be seen that the triple emitter source can be a promising experimental irrigation system; however more studies must be done in order to improve it.

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Tables

Table 1. Christiansen coefficient CUC obtained for the TES experiments (water and salts).

Treatment	NaCl Concentration Irrigation Water (g L^{-1})	CUC (%) Water	CUC (%) Salinity
S1	2.6	98	91
S2	3.8	98	98
S3	4.9	98	95
S4	5.7	99	95
S5	6.6	99	96
S6	7.3	96	94

Figures

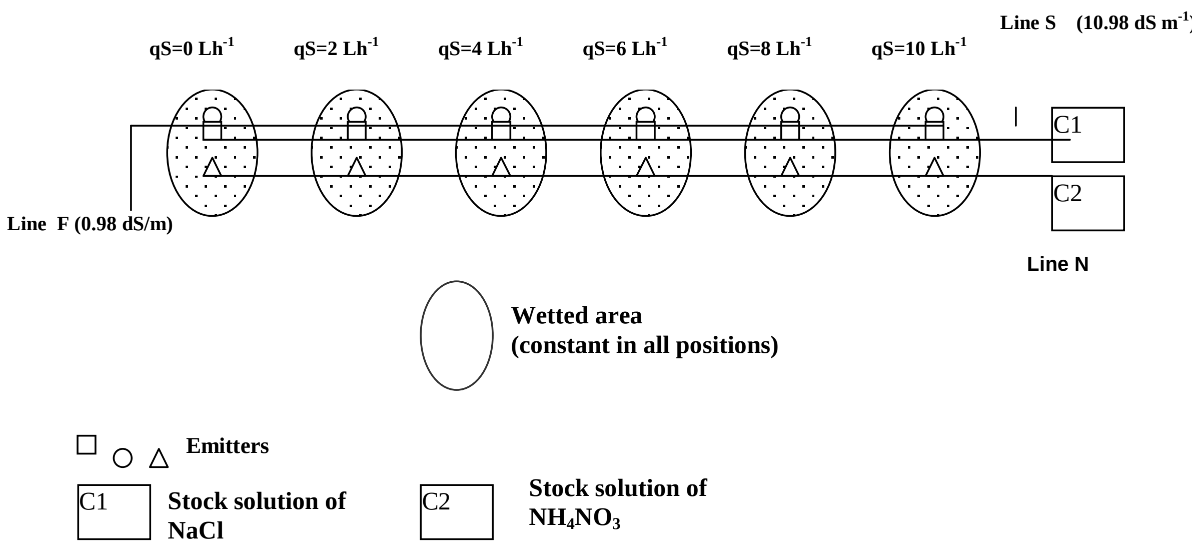

Fig. 1. Layout of the triple emitter source TES design. The three contiguous lines form the triple lateral. The darkness represents increasing salinity. S, N and F lines represent the salt, fertilizer and fresh water trickle lines, respectively.

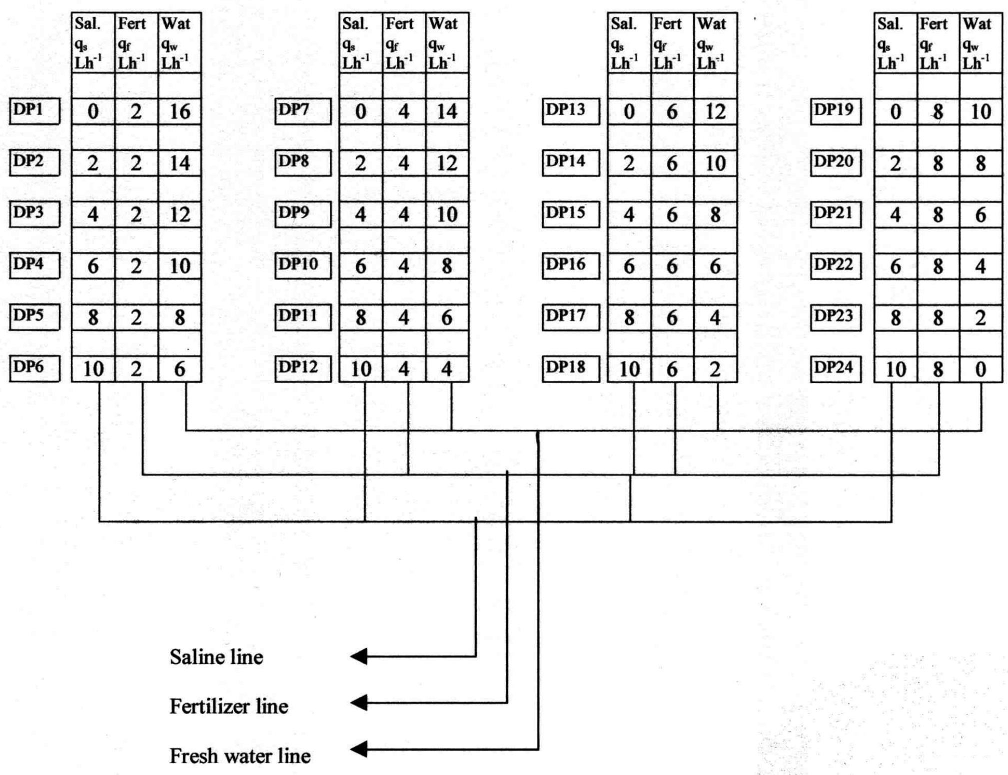

Fig. 2. Layout of the three lines coupled together to form a triple joint lateral used in the triple emitter source TES. The number of dripping points (DP) is 24 The emitters on the three coupled lines have different discharges, provoking different salt and N concentrations, but their cumulative discharge of each dripping point is constant (18 L^{-1}).