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Laboratory evaluation of dripper performance

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ABSTRACT

The catch can method is traditionally used for evaluating performance of drip systems. Two variations of this method are commonly applied in laboratory testing of drippers: the sequential and the simultaneous method. This study compared uniformity and measurement uncertainty of the two methods, with the overall aim of improving irrigation water management. The simultaneous method was found to have a lower coefficient of variation (C_v) and measurement uncertainty, indicating that it is more accurate than the sequential method. In all the tests, however, the C_v was determined to be $<5\%$, which is acceptable as per the current reference standard.

1. Introduction

Drip irrigation is considered to be the most efficient irrigation system, especially for row crops such as vines. As opposed to other pressurised systems such as sprinkler methods whereby water is spread over the entire surface, drippers or emitters supply water directly to small areas in the vicinity of the plant roots at low flow rates (typically 0.5–20 l/h). There is increased scarcity of water resources in many parts of the world, and irrigation is facing competition from domestic and industrial users. There is thus a need to promote water-saving methods such as drip irrigation. On a global scale, the area of land under drip irrigation increased by approximately 5 million hectares between 1986 and 2006 [15].

Drip irrigation systems are designed to deliver uniform amounts of water to the targeted area; however, in practice, water application is typically non-uniform [5,14]. Uniformity of water application is an important aspect under any irrigation system because non-uniform water application results in some portions of the target area being over-irrigated while under-irrigation may occur in other areas, a scenario that may be detrimental to plant growth.

The manufacturer's variation in the production of drippers and hydraulic design aspects are the two major factors that affect the distribution of water in drip systems. Water exits through very small orifices in drippers (typically less than 2 mm diameter), and hence a small deviation in diameter as a result of the manufacturing imperfection may lead to large deviations in flow rates [9]. The design aspects of the drip system such as the operating pressure, spacing between drippers, size and length of the lateral affect the hydraulic characteristics of the flow (for instance friction) and hence the uniformity of water application [16].

Testing and validation of the drip system is an integral step towards the assessment of the efficacy of the technology in terms of optimising water-use efficiency and minimising water losses in irrigated cropping systems. Drip systems may be evaluated under laboratory conditions or in the field. Assessments of the manufacturer's variation in the flow rate of a batch of drippers, for instance, typically require a high degree of precision, and hence are ideally undertaken under laboratory conditions where environmental conditions such as wind and temperature can easily be controlled.

There are a number of specialised laboratories in Australia and overseas that engage in testing of irrigation equipment. Some of these facilities are accredited to national and international bodies, and perform testing according to recognised standards. In the last decade, 18 of these laboratories across 17 countries came together and formed the International Network of Irrigation Testing Laboratories (INITL). The main objective of INITL is to facilitate intercomparison testing of irrigation equipment amongst the member laboratories, with the aim of comparing results and identifying potential opportunities for improvement in their performances. Recent intercomparison testing involving drippers and sprinklers are reported in Koech et al. [12] and Koech et al. [13], respectively. This specific testing exercise involved four laboratories, one each from Australia, Brazil, France and China. The dripper intercomparison testing was undertaken in accordance

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with the International Organisation for Standardisation's ISO 9261 [8], which outlines the specifications and test methods of agricultural drippers.

There are a number of lessons learned, suggestions and conclusions made following the recent dripper intercomparison testing exercise [12]. Key among these is that the reference standard, ISO 9261 [8], is not prescriptive enough in the methodology that should be used to evaluate the dripper performance under laboratory conditions, particularly regarding the determination of the flow rate. Consequently, there are slight variations in the procedures used by different laboratories, making standardisation and intercomparison of results difficult. These variations are evident from a number of studies, for instance, Gamri et al. [4], and Kirnak et al. [10].

A common laboratory procedure used to determine flow rate in drip systems involves the use of catch cans or buckets placed under each dripper in a test rig. Due to lack of standardisation in this respect, there are two main methods used in the placement of catch cans during testing. The first method involves the sequential (one catch can after about every 3 s) placement (at the beginning of the test) and removal (at the end of the test) of catch cans on a platform directly under each dripper. In this paper, this is referred to as sequential testing method and is undertaken manually. In the second method, referred to as simultaneous testing method, testing starts and stops concurrently for all the drippers. This can be done manually, but some laboratories use automatic systems [12]. The sequential method of placing and removing catch cans (one catch can at a time) is more susceptible to errors in the determination of the test duration. Since each catch can is handled individually (and manually), it is impossible to guarantee that the test duration is exactly similar for all the catch cans used in the testing. The measurement uncertainty analysis undertaken in the above dripper intercomparison testing [12] showed that potential errors in the test time had the greatest impact on the accuracy of the results. The study thus recommended the application of methods that eliminate or significantly reduce potential errors in the measurement of the duration of the test.

Our review has shown that no study has been undertaken to analyse the above two common methods used for testing drippers. This paper presents the results of an empirical study undertaken to evaluate the two methods used in the performance evaluation of drippers, with the aim of characterising their efficiencies and the associated measurement uncertainties. The study was undertaken using three sets of drippers, with nominal flow rates: 2, 4 and 8 l/h. It is expected that this research, which investigates the current international standard used for dripper testing, will help to formulate policies and procedures for better management of the scarce water resources in irrigated agriculture.

2. Overview of laboratory dripper testing

Drippers are devices used to discharge water at low flow rates in drip irrigation systems. They may be categorised according to how they are attached to the lateral or their discharge characteristics. Online drippers are attached to the lateral while inline drippers are integrated into the lateral during manufacturing. Regulated drippers (or pressure compensating drippers) are designed to discharge water at constant flow rates over a wide range of operating pressure, while flow rates vary according to pressure in the case of unregulated drippers (or non-pressure compensating drippers).

The standard that is currently used for testing drippers under laboratory conditions is ISO 9261 [8]. These laboratory tests are undertaken to investigate the manufacturing precision of the drippers. The standard recommends the use of a sample of 25 drippers randomly drawn from a pool of at least 500 drippers. Three categories of tests are used to characterise drippers: uniformity of flow rate; flow rate as a function of inlet pressure; and determination of the dripper constant and exponent.

Both ISO 9261 [8] and American Society of Agricultural Engineers' ASAE [1], an alternate standard used in the United States and other countries, recommend the use of the coefficient of variation, (C_v), to determine the uniformity of flow of a sample of drippers. This requires the determination of average flow rate ($\bar{q}$) and standard deviation (S_q) of the sample. The C_v (%) is calculated as follows:

$$C_V = \frac{S_q}{\bar{q}} * 100 \quad (1)$$

Drippers may also be characterised by the flow rate-pressure relationship. Flow rate-inlet pressure curves are obtained by determining the average flow rate (of the 25 drippers) at each pressure level and plotting these against the inlet pressure. The relationship between flow rate, q, and inlet pressure in the dripper, p, can be characterised by the generalised orifice equation of the form:

$$q = k * p^m \quad (2)$$

where k is a constant and m is the emitting discharge exponent. Using the values of flow rates q and their corresponding inlet pressure p, the ISO 9261 [8] recommends the use of the least square method to determine the coefficient k and exponent m.

From Eq. (2), the higher the value of exponent m, the more will the flow rate q be affected by pressure, and vice versa. The value of the exponent m for pressure and non-pressure compensating orifice and nozzle drippers is approximately 0 and 0.5, respectively [9]. The constant, k, is a function of the size of opening and its characteristics.

The ISO 9261 [8] standard does not however prescribe a specific method for measuring dripper flow rate in Eqs. (1) and (2) [12]. Consequently, different testing laboratories employ different methods including: direct volume measurement (for instance using a measuring cylinder); and measuring mass and then converting to volume. Also, unspecified is the minimum volume (or mass) of water required to be collected during the test, and/or the test duration. Volumes commonly used range from 1 to 4 l, while the test duration varies from 5 min to 30 min [12].

Flow rate in either the sequential or the simultaneous method is obtained by dividing the volume of water collected (measured directly or indirectly through the measurement of mass) by the duration of the test. In terms of the accuracy of determining the test duration, it is obvious that there is a higher degree of uncertainty in the results when sequential method is applied. And as noted above, when compared to other potential sources of error, the test time has got the greatest impact on the accuracy of the test results. However, no study has been undertaken to directly compare the two methods (sequential and simultaneous) and characterise their uniformities and associated uncertainties.

3. Materials and methods

3.1. Set-up and test procedures

The dripper tests were conducted at the Australian Irrigation and Hydraulics Technology Centre (AIHTC), at the University of South Australia. This facility is accredited to the National Association of Testing Australia (NATA), and is also a member of the INITL, the international network of laboratories involved in the testing of irrigation equipment such as sprinklers and drippers.

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