Water Distribution Uniformity Improvement of Microtube-type and Button-type Drip Irrigation System Using Adjustable Pressure-Loss Lateral Takeoff Valves

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Abstract

Irrigation application using microtube-type and button-type drip irrigation systems tends to be relatively non-uniform especially under steep slopes and low operating heads. This study was conducted to determine the effect of using a device called Adjustable Pressure-Loss Lateral Takeoff Valves (APLTVs) on water distribution uniformity of both types of drip systems under sloping conditions at various operating heads. A 100 sq. m microtube-type and button-type drip kit developed by the International Development Enterprises (IDE) with and without APLTVs was tested for water distribution uniformity under varying average operating pressure heads and sub-main slope at the facilities of the College of Engineering and Agro-industrial Technology, University of the Philippines Los Baños. A constant head drum water reservoir served as water supply for the IDE drip system. The drip system was operated at average operating pressure heads of 0.5 m, 1.0 m and 1.5 m for slopes of 10%, 20% and 30% for the sub-main and 0% slope for the laterals. The discharge in each emitter was monitored for each chosen slope through direct volumetric measurements. The water distribution uniformity was then evaluated using the Christiansen's method and the Merriam and Keller's method. Results showed that the coefficient of uniformity (CU) and the distribution uniformity (DU) generally increased with APLTVs for all heads and slopes considered for both types of emitters. The water distribution uniformity also improved significantly under sloping conditions at various operating heads with manual adjustment of the APLTVs. Results indicated that the use of APLTVs can significantly improve water distribution uniformity of the low-cost drip irrigation system and offers the potential for maximizing crop yield in upland areas during field application.

Keywords: Drip irrigation, adjustable pressure-loss lateral takeoff valves, coefficient of uniformity, distribution uniformity

1. Introduction

Low-cost drip irrigation is a promising water-saving and water use-efficient technology that can be employed for sustainable upland crop production areas in developing countries such as the Philippines. Its application for dry season cropping and for supplemental irrigation during periods with unreliable rainfall occurrences could increase cropping intensity and sustainability of agricultural production and consequently increase the income of farmers. Like the conventional types of drip irrigation system, it offers special agronomical, agrotechnical, and economical advantages for efficient use of water and labor (Keller, 2002; Keller and Bliesner, 1990). Moreover, the major limitation of conventional drip systems is offset by this low-cost drip technology.

The microtube-type and button-type drip systems are among the low-cost drip irrigation systems developed by the International Development Enterprises, a non-profit organization dedicated to ending poverty in the world (Polack et al., 1997). These low-cost drip irrigation systems basically consist of either microtubes or buttons serving as emitters inserted into plastic tube (layflat tape when empty) laterals connected to polyethylene submain pipes which in turn can be connected to a drum water reservoir or a tank. The system can be operated by elevating the drum reservoir at appreciable head thereby eliminating the need for a pumping unit and consequently reducing the cost of operation. The typical operating head of the IDE drip kits ranges from 1.0 m to 3.0 m (Keller, 2002).

The manufacturing cost for this type of drip system is relatively low making the whole package more cost-effective than conventional drip systems. Furthermore, it does not depend on fossil fuel-based pumping units to generate the necessary operating pressure. The IDE has reported that this drip technology has the potential to reduce environmental impact by cutting hydrocarbon emissions associated with traditional diesel-based irrigation systems by 308,000 tons over four years, offering water savings of 30 to 50 percent per family, and mitigating soil erosion through drip irrigation's highly targeted water use (IDE, 2008).

Nevertheless, irrigation application using microtube-type and button-type drip irrigation systems tends to be relatively non-uniform especially under steep slopes and low operating heads. In a previous study by Ella et al. (2009), the uniformity coefficient and distribution uniformity of the microtube-type drip system are relatively low especially for steep slopes and low heads. It was consequently recommended in that study to explore the use of pressure regulator in improving the water distribution uniformity of the low-cost drip system. On the other hand, the button-type drip irrigation system remains untested for water distribution uniformity with and without pressure regulators. Hence, this study was conducted to determine and evaluate the effect of using a device called Adjustable Pressure-Loss Lateral Takeoff Valves (APLTVs) on water distribution uniformity of both the microtube-type and button-type drip irrigation systems under sloping conditions at various operating heads.

2. Methodology

Microtube-type and button-type drip kits, each with a service area of 100 sq. m, were chosen randomly and tested for water distribution uniformity with and without APLTVs at the facilities of the College of Engineering and Agro-industrial Technology, University of the Philippines Los Baños. A constant head drum water reservoir served as water supply and pressure regulator for the IDE drip system. The drip system was operated at average operating pressure heads of 0.5 m, 1.0 m and 1.5 m for slopes of 10%, 20% and 30% for the sub-main and 0% slope for the laterals. The laterals were spaced 1 m apart. Each of the ten (10) laterals has thirty three (33) evenly-spaced emitters for a total of 330 emitters for the whole system. The emitter spacing was 30.0 cm. For each setting, emitter discharge was determined through direct volumetric measurements from eleven (11) emitters in each lateral for a total of 110 samples. Three replications were done for each slope and head setting.

The discharge data were consequently used for evaluating the water distribution uniformity. Two indices of uniformity were used in this study, namely the Christiansen's coefficient of uniformity and the Merriam and Keller's emission uniformity.

3. Results and Discussion

3.1. The microtube-type drip irrigation system

The calculated coefficient of uniformity (CU) and distribution uniformity (DU) values for various operating heads and slopes with and without APLTV adjustment for the microtube-type drip system are depicted graphically in Figure 1. For all heads, CU generally decreased with increasing slope as to be expected. For a low operating head of 0.5 m and without APLTV adjustment, the average CU ranged from 52.9% to 78.4%. With APLTV adjustment for this same head, the average CU was increased to a minimum of 85. 4% to a maximum of 89.7%. On the other hand, for a high operating head of 1.5 m, the average CU ranged from 79.0% to 91.4% without APLTV adjustment. This range was increased to up to 94.1% with APLTV adjustment. The same improvement in CU was observed for the moderate operating of 1.0 m with average CU ranging from 71.8% to 87.7% without APLTV adjustment and from 82.1% to 92.3% with APLTV adjustment. A paired t-test (α=5%) showed that there is significant increase in CU for all heads and slopes dealt with except for a head of 1.5 m and 20% to 30% slope. For these exceptional cases, however, the CU values with and without APLTV adjustment were still relatively higher than those obtained from the previous study of Ella et al. (2009).

In terms of distribution uniformity (DU), the same pattern was observed with the average DU values generally decreasing with increasing slope for all operating heads. However, the DU values for each setting were relatively lower compared to the corresponding CU values. This is as to be expected as DU values take into account the extremely low emitter discharge values relatively to the mean discharge value. For a low operating head of 0.5 m, the average DU values ranged from 79.0% to 84.1% with APLTV adjustment. This is a marked improvement with APLTV adjustment, which indicated an average DU value of 24.9% to 64.1%. Under a high operating head of 1.5 m, the DU values ranged from 68.2% to 87.9% without APLTV adjustment. This range was increased to a maximum average DU of 90.7% with APLTV adjustment. For a moderate head of 1.0 m, the average DU values ranged from 55.4% to 79.8% without APLTV adjustment and from 75.0% to 88.7% with APLTV adjustment. For all settings, the DU was increased significantly with APLTV adjustment based on t-tests except for a head of 1.5 m and 20% to 30% slopes as in the case of CU. Nevertheless, the DU values obtained in these experiments were generally higher compared to the previous results of Ella et al. (2009) without the APLTV.

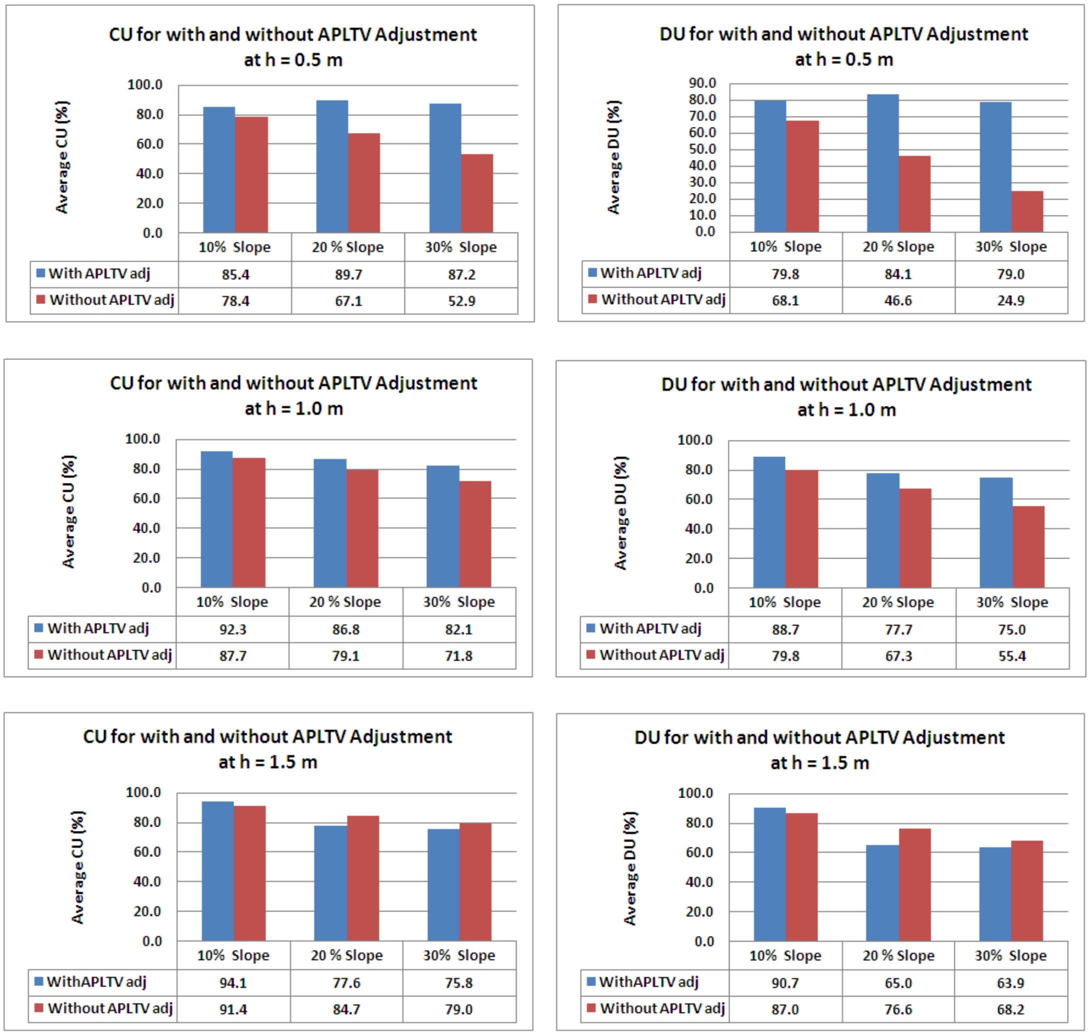

Figure 1. Coefficient of uniformity and distribution uniformity of microtube-type emitter drip system at various slopes and heads with and without APLTV adjustment.

3.2. The button-type drip irrigation system

The average CU and DU values for all operating heads and submain slopes used for the button-type drip system are shown in Figure 2. Both the CU and DU values generally decreased with increasing submain slope similar to the microtube-type drip system. More importantly, both CU and DU generally increased with APLTV adjustment for all heads and slopes.

For low operating head of 0.5 m, the average CU values ranged from 68.9% to 75.1% without APLTV adjustment. This range was increased to 77.6% with APLTV adjustment. Although the values appear to be close, t-tests showed that the CU values are significantly different for each pair of values for each slope (α=5%). For a high head of 1.5 m, the CU values ranged from 79.1% to 81.7% without APLTV adjustment. This was increased to 83.2% with APLTV adjustment. However, pairwise comparison using t-tests (α=5%) showed that the differences are not significant. The CU values under this head were nonetheless relatively higher with APLTV

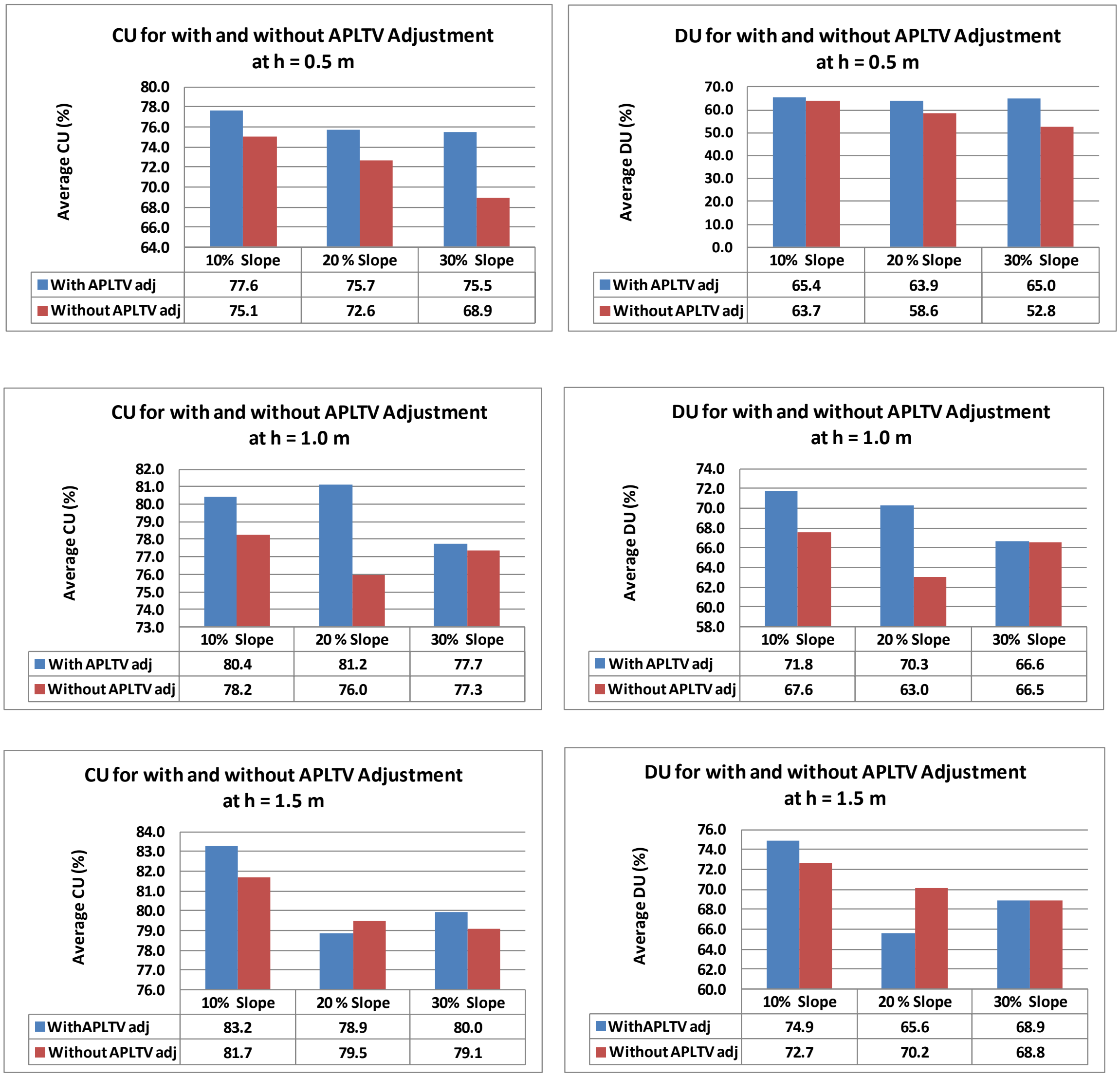

Figure 2. Coefficient of uniformity and distribution uniformity of button-type emitter drip system at various slopes and heads with and without APLTV adjustment.

adjustment than without adjustment except for 20% slope. For a moderate operating head of 1.0 m, the same improvement in CU is noticeable with average CU ranging from 76.0% to 78.2% without APLTV adjustment and from 77.7% to 81.2% with adjustment. The CU values under this head were significantly different (α=5%) except for 30% slope.

On the other hand, the distribution uniformity (DU) values were relatively lower than the CU values for each setting similar to the microtube-type drip system. Again this is to be expected as DU considers the extremely low emitter discharge values relative to the average value. More importantly, the DU values generally improved with APLTV adjustment. For a low head of 0.5 m, the average DU values ranged from 63.9 to 65.0% with APLTV adjustment compared to only 52.8% to 63.7% without APLTV adjustment. For a high head of 1.5 m, the average DU without

APLTV adjustment ranged from 68.8% to 72.7%. With APLTV adjustment, the average DU was increased to 74.9%. The same improvement on DU with APLTV adjustment was evident for a moderate operating head of 1.0 m. However, a pairwise comparison of DU values with and without APLTV adjustment showed that the differences were relatively insignificant for a high head of 1.5 m for 10 to 30% slope and for moderate head of 1.0 m and slopes of 20% to 30%. Nevertheless, the DU values were generally higher with APLTV adjustment than without adjustment except for a head of 1.5 m and slope of 20%.

4. Summary and Conclusion

This study was conducted to determine and evaluate the effect of using a device called Adjustable Pressure-Loss Lateral Takeoff Valves (APLTVs) on water distribution uniformity of both the microtube-type and button-type drip irrigation systems under sloping conditions at various operating heads. A 100 sq. m microtube-type and button-type drip kit was tested for water distribution uniformity under average operating pressure heads of 0.5 m to 1.5 m and sub-main slopes of 10% to 30% with and without APLTVs at the facilities of the College of Engineering and Agro-industrial Technology, University of the Philippines Los Baños.

Results showed that both the coefficient of uniformity (CU) and the distribution uniformity (DU) generally increased with APLTVs for all heads and slopes considered for both types of drip systems. The water distribution uniformity also improved significantly under sloping conditions at various operating heads with manual adjustment of the APLTVs. For the microtube-type drip system, the average CU ranged from 75.8% to 94.1% with APLTV adjustment and from only 52.9% to 91.4% without APLTV adjustment for all slopes and heads considered. For the same type, the average DU ranged from 63.9% to 90.7% with APLTV adjustment and from only 24.9% to 87% without adjustment. Pair-wise comparison of CU and DU values for each setting using t-tests showed significant differences except for steep slopes. For the button-type drip system, the average CU ranged from 75.5% to 83.2% with APLTV adjustment and from 68.9% to 81.7% without adjustment. The average DU ranged from 63.9% to 74.9% with APLTV adjustment as compared to a range of 52.8% to 72.7% without adjustment. Pair-wise t-tests also showed significant differences in CU and DU values with and without APLTV adjustment except for steep slopes.

Results of this study provided empirical evidence that indeed the Adjustable Pressure-Loss Lateral Takeoff Valves (APLTVs) could significantly improve the water distribution uniformity of the low-cost drip irrigation system using microtubes or button emitters. Consequently, this technological improvement offers the potential for maximizing crop yield during field application particularly in upland crop production systems employing this type of irrigation technology.

4. Acknowledgement

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