EMITTER UNIFORMITY COEFFICIENT AS AFFECTED BY LATERAL SLOPES AND SIZES

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ABSTRACT

Emitter uniformity coefficient is a very important factor to judge the design of drip irrigation system. An experimental study has been made to investigate the effect of lateral slope, size and length on the emitter uniformity coefficient in drip irrigation. The study involved five lateral slopes and three common lateral sizes have different lengths. Results of the investigation indicated that the uniformity coefficient decreases as the increase of the lateral pipe length and slope while it increases rapidly as the increase of the lateral diameter.

Keywords: Drip, Emitters, Lateral, Uniformity coefficient

INTRODUCTION

Irrigation is the largest consumer of water and, hence, must be given a great deal of attention. To obtain the maximum utilization from the limited water resources, it is necessary to use the water with the maximum possible efficiency. Drip irrigation is an efficient method of providing water directly *into the soil at the root zone of* plants. It permits the irrigator to limit the watering closely to the consumptive use of the plant. Thus, drip irrigation minimizes such conventional losses as deep percolation, runoff and soil evaporation. A drip irrigation system consists of a main line, submains, lateral and emitters. The emitters, which are attached to laterals, distribute water for irrigation. The outflow of each emitter is controlled by the pressure distribution along the submain and lateral lines. This distribution is controlled by the energy drop through friction losses and the energy gain or loss due to slopes either down or up [1]. The loss or gain in pressure is linearly proportional to the slope and length of the line [2]. When a lateral line laid up or down slopes it will affect the pressure distribution along the line. When it is laid up it will lose pressure and when it is laid down it will gain pressure. The curve of friction drop combined with the pressure gain or loss due to down slopes or up slopes determine the pressure distribution along the lines. Due to the characteristics of drip irrigation where the discharge in the lateral is decreasing with respect to the length, the friction loss along the lateral is not linearly proportional to the length but is an *exponential* function of the length of the lateral [3]. The ideal drip irrigation system is one in which all emitters deliver the same volume of water in a given irrigation time. Practically, it is difficult to achieve this ideal performance due to the variation of water pressure and topography. As a result, the flow rate of the different emitters will vary. In arid and semi arid regions conditions, where atmospheric demand is very high, the knowledge of the uniformity of water distribution from emitter is important to insure efficient irrigation practice. Wu and Gitlin [3] stated that the variation of discharge from emitters along a lateral line is a function of the lateral length, inlet pressure, emitter spacing and total flow rate. Since the emitter flow is controlled by the pressure distribution, the emitter discharge distribution can be determined.

The degree of uniformity of emitter outflow throughout the lateral can be shown by

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using the Christiansen uniformity coefficient UC [4] It is defined as:

$$UC = (1 - \left[\frac{1}{nq_{av}}\right] \sum_{i=1}^{n} |q_i - q_{av}|) \times 100 \qquad (1)$$

where:

q_{av} = average emitter outflow.
q_i = outflow of emitter i.
n = number of emitters.

The uniformity coefficient is a quantitative expression of the emitter flow variation. Knowing the discharge distribution, the uniformity coefficient distribution along the lateral can be determined. [4] considered that a uniformity coefficient of 98% or more is desirable, while values from 95% to 98% are considered to be acceptable. A uniformity coefficient of less than 95% is not recommended. Many previous studies investigated the analysis and design of the drip irrigation system. Based on analytical and experimental study, Wu *et al.* [2] presented charts to design drip irrigation lateral line and used the uniformity coefficient to judge the design. Wu and Gitlin [5], Howell and Hiller [6] Hathoot *et al.* [7] and Al-Amoud *et al.* [8] developed computer programs for analyzing and designing laterals considering the lateral uniform slopes S, and based on the calculated UC, they can judge the design. They also showed that UC decreases as the increase of the lateral pipe length. Kang and Nishiyama [9] used the finite element method to analyze the pressure distribution of a large microirrigation system. Al-Amoud [10] and Bagarello *et al.* [11] studied experimentally the effect of emitter connection on the energy loss in the laterals. They concluded that the effect of barb area is more significant at smaller pipe diameter (13 mm) compared with larger diameter. Moghazi and Ismail [12] tested different common types of emitters in Al-Qassim area, Kingdom of Saudi Arabia. They concluded that the turbo-key emitter (turbulent flow type) has shown a satisfactory performance of uniformity and manufacturer variation. Considering experimentally the effect of the slope, diameter and length of the lateral on the uniformity, however, very few studies have found.

A need for more understanding of the variation of the uniformity coefficient caused by the lateral dimensions and slopes is required. Therefore, an effort is made in this study to investigate experimentally the effect of lateral slope, size and length, on the emitter uniformity.

MATERIALS AND METHODS

The experiments were conducted at the Hydraulic Laboratory, King Saud University, Al-Qassim, Saudi Arabia. Three common diameters of polyethylene pipes were tested (13, 16 and 19 mm). These represent the practical sizes used in the field. Two lengths were chosen for each pipe diameter (L = 10 and 20 meter). The lateral pipes were carefully selected to avoid any irregularities in the pipes. Considering the study of Moghazi and Ismail [12], identical Turbo-Key emitters with nominal discharges of 4 l/h at 100 kPa were selected for the emitter devices. Emitters were inserted into the laterals every 1 m. Water obtained from an elevated tank and was pressurized into the lateral by 0.75 kW (1 hp) centrifugal pump. Water depth was maintained constant in the tank by a float controlled valve connected to a domestic water supply. The laboratory is well air conditioned and the water temperature is about 25°C±1. A new calibrated pressure gauge was installed at the lateral inlet. The study was carried out under an operating pressure P equals to 100 kPa at the lateral inlet. The operating pressure was controlled by a gate valve fitted after the pressure gauge. Five lateral slopes S were investigated (-5 %, -3 %, 0, +3 %, +5 %). Minus signs mean down slopes while positive signs mean up slopes. Lateral slope was obtained by using different pieces of wood. The upper surface of each piece was designed to give the proposed slope. Each lateral was firstly laid on a horizontal metal bench. A catch can was put underneath each position of emitter to collect the dripped water. Applying the operating pressure P at the lateral inlet, the flow of each emitter at a distance X from the lateral inlet was determined using a graduate cylinder and digital stop watch. This procedure was repeated for all lateral lengths, diameters and slopes. Consequently, the corresponding emitter uniformity coefficient UC was determined using equation (1).

RESULTS AND ANALYSIS

Figures 1 and 2 show the relationship between the lateral length ratio X/L and the uniformity coefficient UC at different lateral diameters and slopes for L = 10 and 20 m respectively. It can be seen that the uniformity decreases rapidly along the lateral length. The maximum value of UC is noticed at the lateral inlet while the lowest value is noticed at the end of the lateral. This is attributed to the fact that the emitter discharge decreases along the lateral length. It can also be seen from these figures that the uniformity decreases as the increase of the lateral slop S_o. When the lateral is laid up slope it will lose pressure, and when it is laid down slope it will gain pressure. The maximum uniformity is noticed at S = -5%, while the lowest uniformity is noticed at S_o = +5%. For instance, at the outlet of the lateral 13 mm diameter, the uniformity coefficients are 89% and 70% at S = -5% and 5% respectively. Meanwhile, at the lateral outlet 19 mm diameter, the corresponding uniformity coefficients are 92% and 78% respectively.

In order to investigate the effect of the lateral pipe length on the uniformity coefficient, comparisons are made between the two lateral lengths (L = 10 and 20 m) at the middle and the end of the lateral as shown in Figures. 3 and 4. It can be noticed from these figures that the values of the uniformity coefficient at pipe length = 20 m are always less than the corresponding values at lateral pipe length = 10 m, regardless the lateral slope is either up or down.

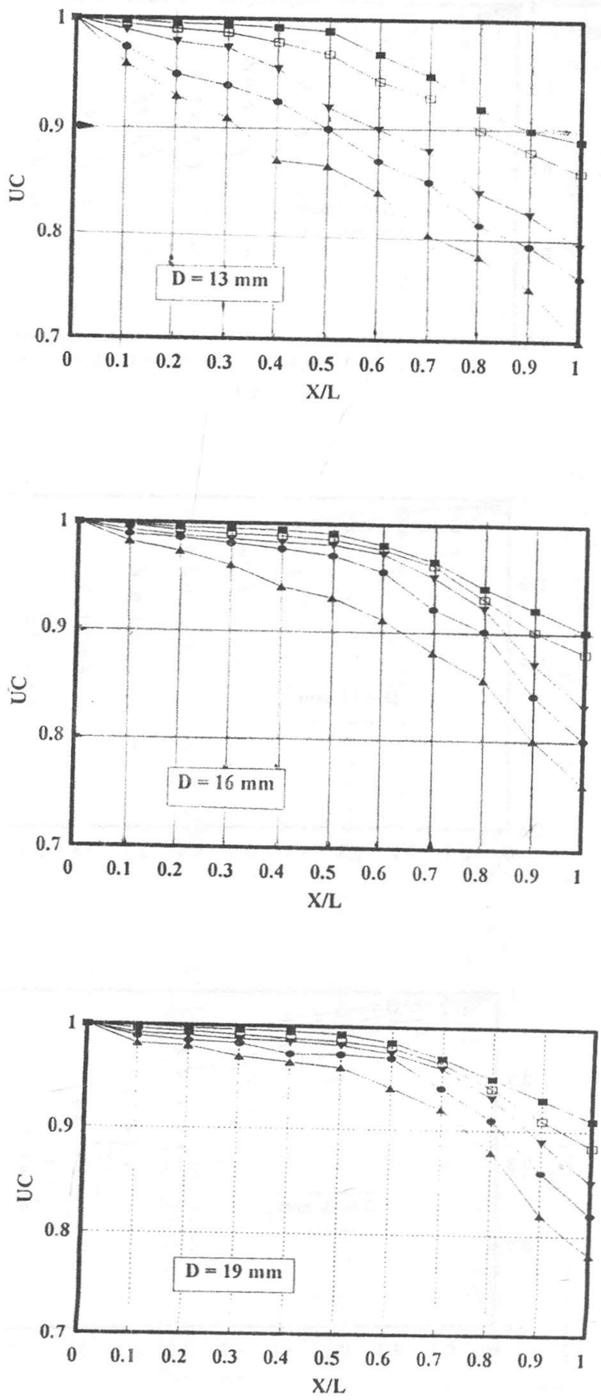

Figure 1 The distribution of uniformity coefficient along the lateral length (L=10m)

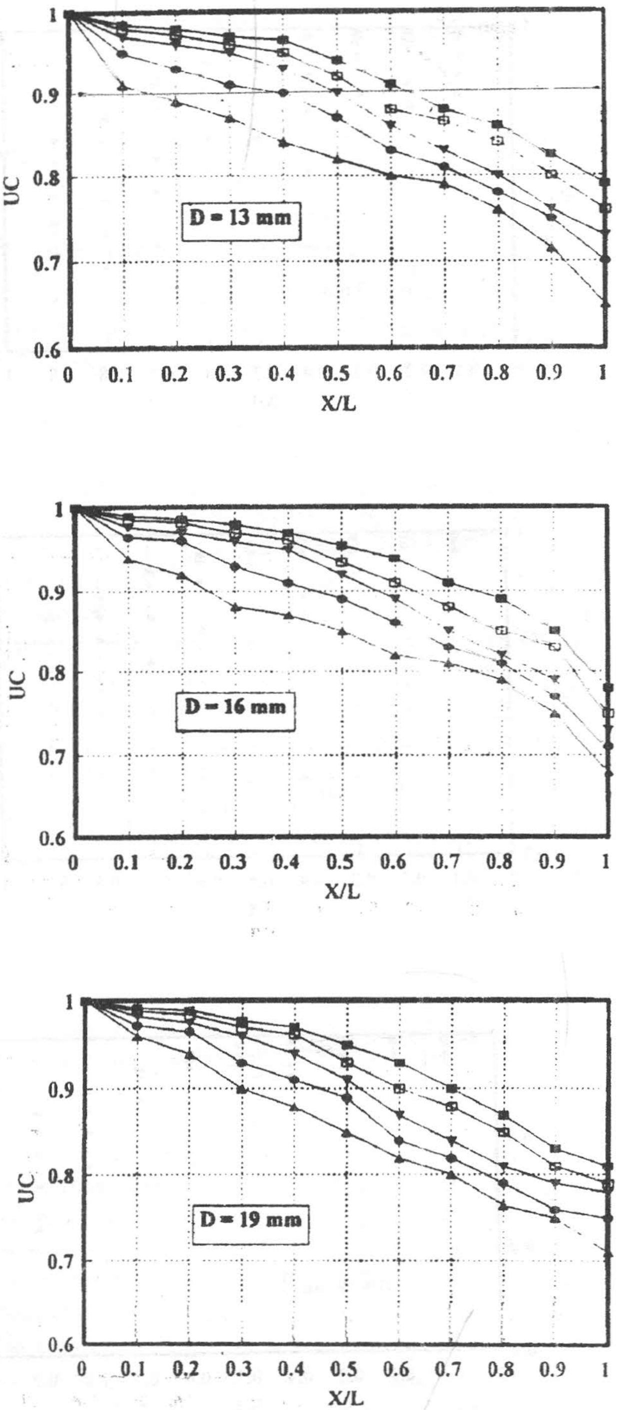

Figure 2 The distribution of uniformity coefficient along the lateral length (L=20m)

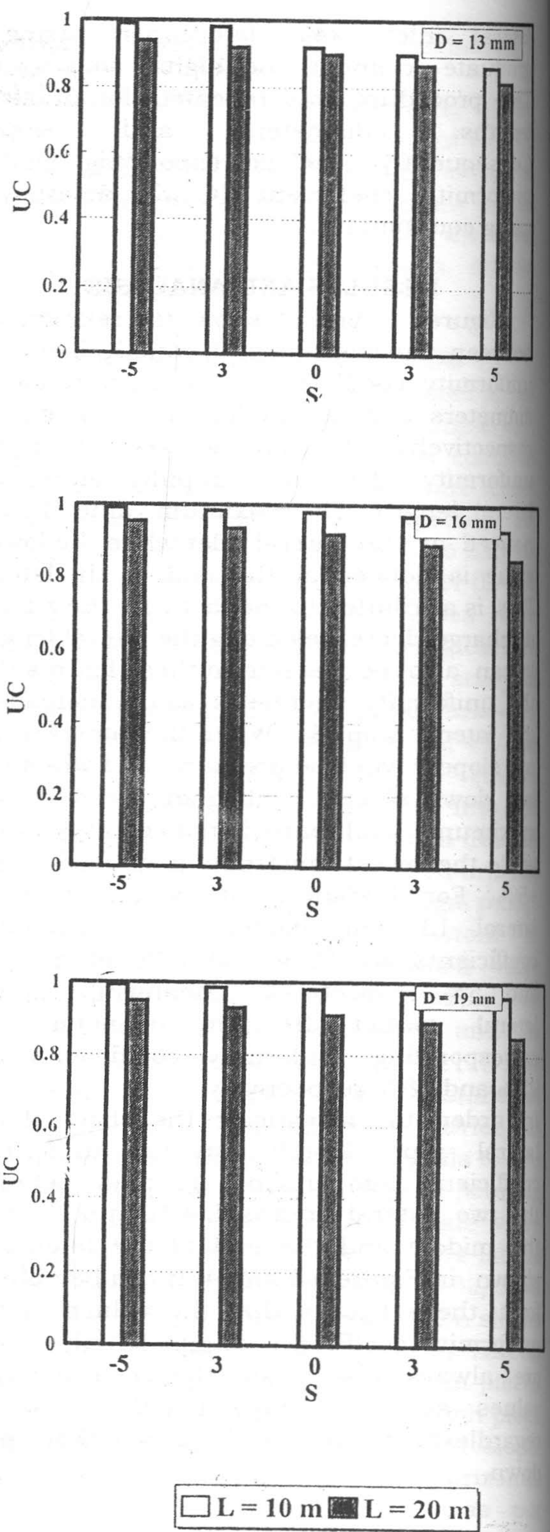

Figure 3 Comparisons between the uniformity coefficients at different lateral lengths (at the middle of the lateral)

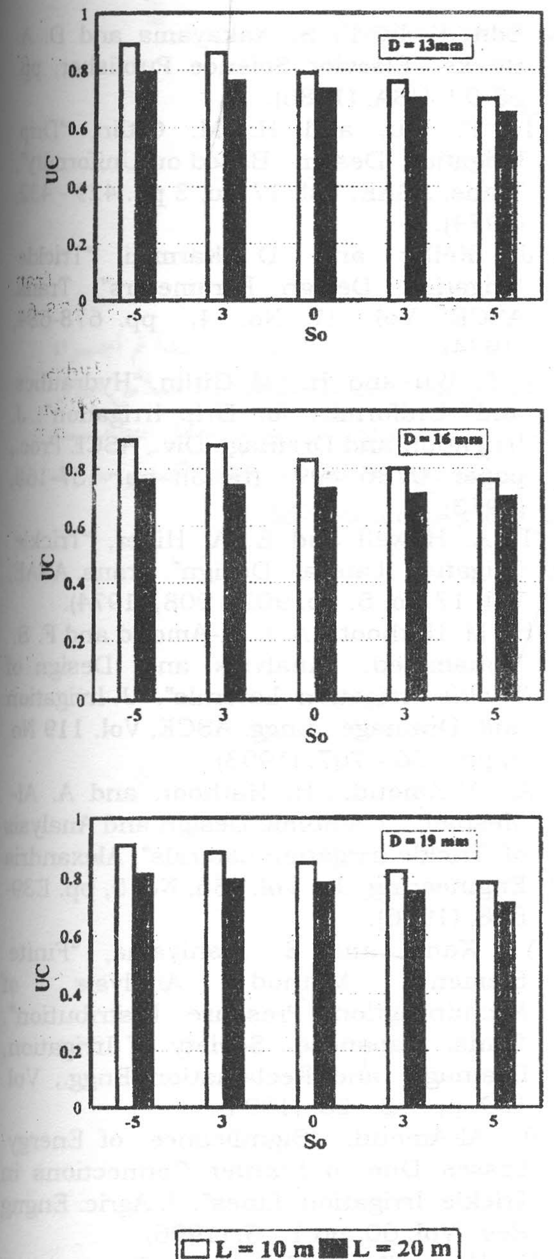

Figure 4 Comparisons between the uniformity coefficients at different lateral lengths (at the middle of the lateral)

For instance, at lateral 13 mm diameter with a slope of -5%, the values of UC are 99% and 94% at L = 10 and 20 m respectively. Meanwhile, at the same lateral diameter with a slope of +5%, the corresponding values are 86.5% and 82% respectively. This is because the energy loss due to friction and emitter's barb increases as lateral length increases. This means that the uniformity coefficient is inversely related to the pipe length.

In order to investigate the effect of the pipe diameter D on the uniformity coefficient, comparisons between the three pipe diameters for different slopes are made at the middle and the end of the laterals as shown in Figures 5 and 6 respectively. The comparisons show that the uniformity coefficient increases as the increase of the pipe diameter. For instance, at the end of 20 m lateral length with a slope 5%, the uniformity increases from 65% at lateral pipe 13 mm diameter to 75% at 19 mm diameter. This is attributed to the relative area effect (area of emitter barb/pipe cross-sectional area) which is greater for smaller pipe diameters. As a result, the energy loss increases as the decrease of the pipe diameter causing a decrease in the emitter uniformity.

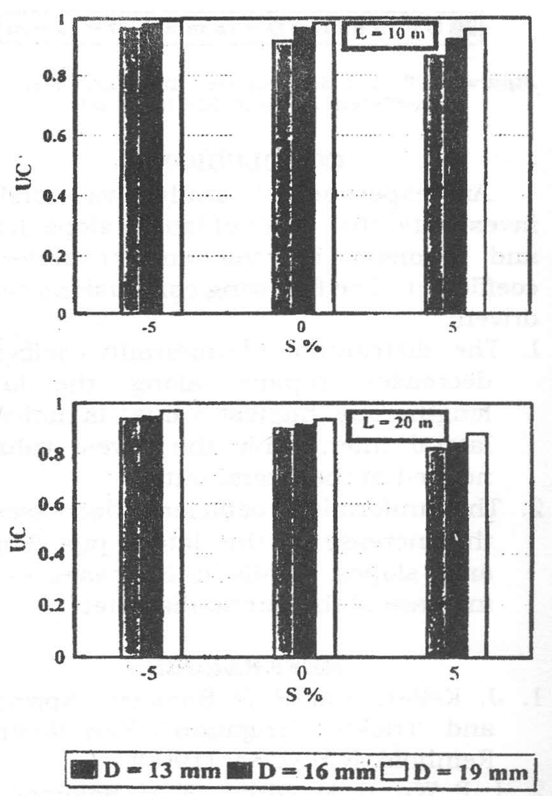

Figure 5 Effect of pipe diameter on the uniformity coefficient at the middle of the lateral

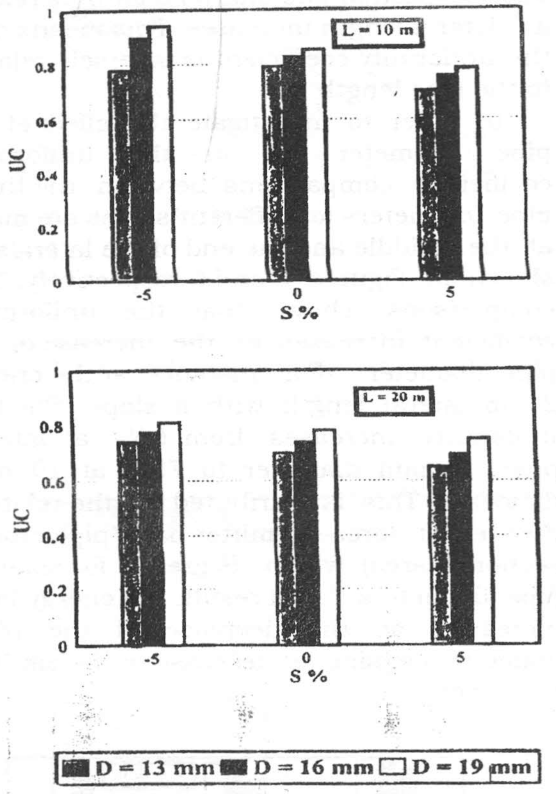

Figure 6 Effect of pipe diameter on the uniformity coefficient at the middle of the lateral

CONCLUSIONS

An experimental study was made to investigate the effect of lateral slope, length and diameter on the emitter uniformity coefficient. The following conclusions can be driven:

1. The distribution of uniformity coefficient decreases rapidly along the lateral length. The highest value is noticed at lateral inlet, while the lowest value is noticed at the lateral outlet.
2. The uniformity coefficient decreases as the increase of the lateral pipe lengths and slopes, while it increases as the increase of the lateral diameter.

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تأثر انتظامية المنقط بميول وأبعاد الخط الحامل للمنقطات

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ملخص البحث

يعد معامل إنتظامية المنقط من أحد العوامل الهامة جدا في الحكم على جودة تصميم نظم الري بالتنقيط. ولـــذا تم أجـــراء تجربة معملية لاستكشاف تأثير كل من ميل وقطر وطول الخط الحامل للمنقطات على معامل انتظامية المنقط. وتم هذا من خلال دراسة خمسة ميول وثلاث أقطار شائعة لأطوال مختلفة للخط الحامل للمنقطات. وقد بينت نتائج الدراسة أن معامل انتظاميـــة المنقط يتناقص مع زيادة كل من طول وميل الخط الحامل للمنقطات بينما يتزايد بشدة مع زيادة قطر هذا الخط. كما لوحظ إن أقصى قيمة لمعامل الانتظامية توجد عند بداية الخط الحامل للمنقطات وأن أقل قيمة توجد عند نهاية الخط.