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HYDRAULIC PERFORMANCE OF TRICKLE IRRIGATION EMITTERS UNDER FIELD CONDITION

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The efficiency of trickle irrigation system depends on the uniform distribution of water through mechanical device, the emitter. The aim of this research study was to compare and evaluate the hydraulic performance of pressure-compensating and non pressure-compensating emitters under field condition. Both types of emitters were subjected to different operating pressures (50,100,150,200 and 250KPa) of the water source. Three hydraulic performance parameters including manufacturer's coefficient of variation, hydraulic design's coefficient of variation and total coefficient of variation were tested for pressure-compensating and non pressure-compensating emitters. Manufacturer's coefficient of variation (CV_M) values was compared with test results for both types of emitters. Hydraulic design's and total coefficients of variations were also determined at field level. The results showed that pressure-compensating emitters has less dependency on operating pressure as compared to non pressure-compensating ones which was further clarified trough statistical analysis by their linearity at 95% confidence and prediction intervals.

Keywords: Emitters, Hydraulics, Turbulence, Energy, Micro-irrigation

1. Introduction

Optimum management of available water resources at farm level is needed because of increasing demands, limited resources, water table variation in space and time and soil contamination, while efficient water application is one of the key elements in successful operation and management of irrigation schemes [1]. The drip irrigation system offers the highest irrigation uniformity compared with other irrigation systems. Designers of micro irrigation systems need to know how specific products will perform under conditions experienced in the field. The goal is to design a system that will have a hydraulic balance such that a subunit within the system has a known and uniform emitter discharge, most design concerns focus on the operating pressure/emitter discharge relationships of the emitters [2]. However, emitter discharge rates and the uniformity of a micro irrigation system are also influenced by other factors such as manufacturing variability [3-6].A successful uniform drip irrigation system application depends on the physical and hydraulic characteristics of the drip tubing [7] more ever in surface drip irrigation systems, uniformity can be evaluated by direct measurements of emitter flow rates [8]. Several researchers worked in order to design efficient irrigation systems at farm level [9-12] these appear to be a very crucial aspect for the irrigated agriculture and a key factor due to the competition for water resources however, they did a little focus to the emitter hydraulics performances caused by manufacture, design and its combine effect as compared to evaluate the whole system. The present study was, therefore, conducted to compare the performance of pressure-compensating and non pressure-compensating emitters at field level.

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2. Materials and Methods

2.1, Research Site and Design Data

The study was conducted in Agriculture Research Institute, Tarnab, Peshawar in a recently developed olive orchard (34^0 32'N,72^0 25'E , 348m SL). The online pressure-compensating and non pressure-compensating emitters were used having a discharge of 10 Lh^{-1} with 3 meters space between two adjacent emitters. Average Laterals length was 36 m with an inner diameter of 16mm while each lateral had 12 numbers of emitters. The space between two laterals was kept 6m. PVC pipe were used for main and sub-main in the system. The inner diameter of main was ranging from 5-6cm with a length of 280 m while for sub-main the inner diameter was 5cm with 175m length. Both laterals were controlled by one hydro zone. All the emitters were tested against 50,100,150,200 and 250KPa as described by Kirnak *et al*.(2004) while keeping the emitter exponent value 0.04 for pressure compensating and 0.6 for non pressure compensating emitters. The laterals were kept above from ground using bamboo and plastic wire in order to keep the laterals at the same elevation to avoid variation of emitter discharge due to energy gradient as well as plugging of emitters.

2.2. Calibration of the System and Field Data Collection

Prior to start the experiment the system was calibrated in order to find that all the emitters delivered the same discharge. The flow rate of emitters was assessed by using 1000ml graduated cylinder and stop watch. The system was run for specific time to attain the uniformity in flow rate. Pressure gauges were used to monitor pressure at each emitter point and thermometer was used to determine the temperature of water.

2.3. Hydraulic Performance of Emitters

Three coefficients of variation for emitter [14] were conventionally used to assess hydraulic performance of emitters. These are (I) Coefficient of variation of emitter flow caused by manufacturer's variation, CV_M (II) Coefficient of variation of emitter flow caused by hydraulic design, CV_H and (III) Coefficient of variation of emitter's flow caused by hydraulic design and manufacturer's variation CV_{HM}.

2.3.1. Manufacture's Coefficient of Variation

Manufacture's Coefficient of Variation was determined from flow rate measurement from emitters and is computed as follow:

$$CV_M = \frac{(q_1^2 + q_2^2 + ... + q_n^2)^{1/2}}{\bar{q}(n-1)^{1/2}} \qquad (1)$$

where, CV_M is Manufacturer's Coefficient of Variation and q_1, q_2, q_3 are discharges of emitters (Lhr^{-1}), n is the number of emitters and $\bar{q}$ is Average flow rates (Lh^{-1}). Manufacturer's Coefficient of Variation has been verified by the American Society of Agriculture Engineering recommendations.

2.3.2. Hydraulic Design's Coefficient of Variation

Considering hydraulic variation only, the CV of emitter flow and the emitter flow variation q_{var}, can be expressed by [15]. Emitter flow variation equation is as follow

$$CV_H = 0.4467 q_{var} - 0.0026 \qquad (2)$$

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \qquad (3)$$

where q_{var} is the emitter variation, q_{max} is the maximum emitter flow and q_{min} is the minimum emitter's flow.

2.3.3. Total Coefficient of Variation

CV_{HM} is calculated from eq-IV.

$$CV_{HM} = CV_M + CV_H \qquad (4)$$

2.4. Statistics Methods

Statistical analysis of all the performance parameters was done at 95% class interval for 95% prediction intervals.

3. Results and Discussion

On the basis of manufacturer's coefficient of variation the pressure-compensating and non pressure-compensating emitters were categorized as excellent and marginal respectively. As Figure 1 showed that coefficient of variation in pressure-compensating emitters varied slightly with increasing pressure as compared to non pressure-compensating emitters (Figure 2) a fact that can be statistically confirmed by coefficients of determinations R^2=0.83 and R^2=0.97 for pressure-compensating emitters and non pressure-compensating emitters respectively. When comparing both variations, some dispersion occurred of the data around the fitted 1:1 lines of 95% confidence and prediction intervals. High linearity existing between operating pressure and non pressure-compensating emitters as compared to pressure-compensating ones, this indicated the pressure-compensating rely less on source pressure up to some extent as compare to non pressure - compensating emitters. The non - pressure compensating emitters variation increased when the operational pressure had increased, as was expected. On the other hand, the compensating emitters variation was almost in

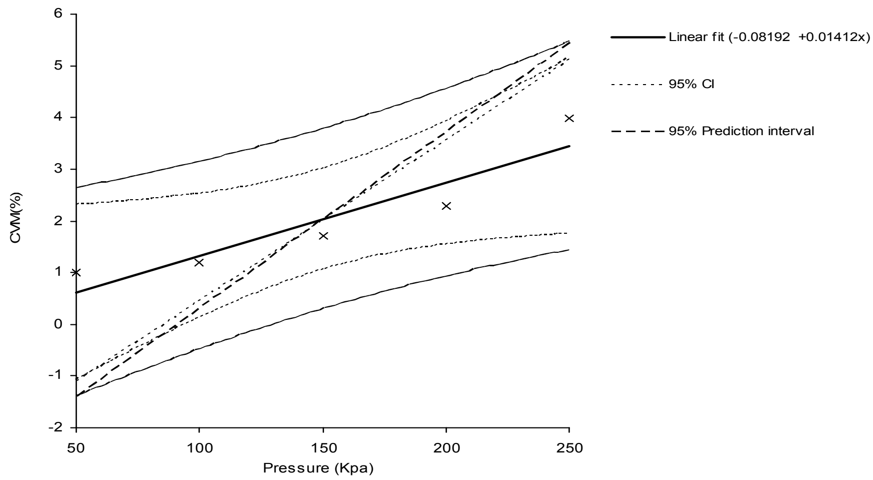

Figure 1. Manufacturer's coefficient of variation of pressure-compensating emitters with respect to different operating pressure of water source.

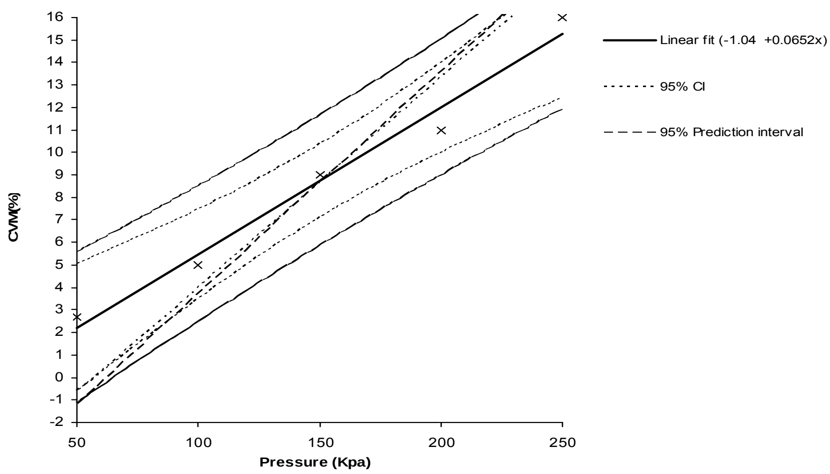

Figure 2. Manufacturer's coefficient of variation of non pressure-compensating emitters with respect to different operating pressure of water source

Table 1. ASAE (1996) recommended classification of manufacturer's coefficient of variation (CV_M)

CV_M (%)	Classification
<5	Excellent
5-7	Average
7-11	Marginal
11-15	Poor
>15	Unacceptable

the excellent category under different operating pressures, again as was expected. It is mainly due to the ability of pressure-compensating emitters that it allows the uniform distribution of water inside the pipe and overcome the turbulence caused by high operating pressure while the non-compensating emitters lack such ability and hardly can predict the response of variation above than 250KPa operating pressure of the water source as reported by Kirnak et al. (2004).

Table 2. Average discharge variation of pressure compensating emitters(P.C.E) and non pressure-compensating emitters (N.P.C.E) at different operating pressure (O.P) of water source.

O.P(KPa)	P.C.E q_{var} (%)	N.P.C.E q_{var} (%)
50	0.79	9
100	0.83	21.3
150	0.88	27.1
200	0.94	33.72
250	0.98	39.51

Table 2 shows the average pressure-compensating and non pressure-compensating emitters discharge variation with respect to different operating pressures of the water source. The

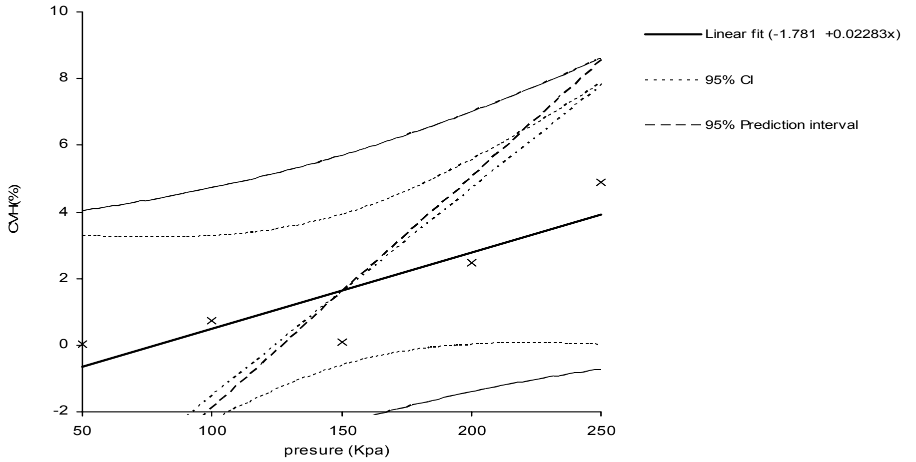

Figure 3. Hydraulic design's coefficient of variation of pressure-compensating emitters with respect to different operating pressure of water source.

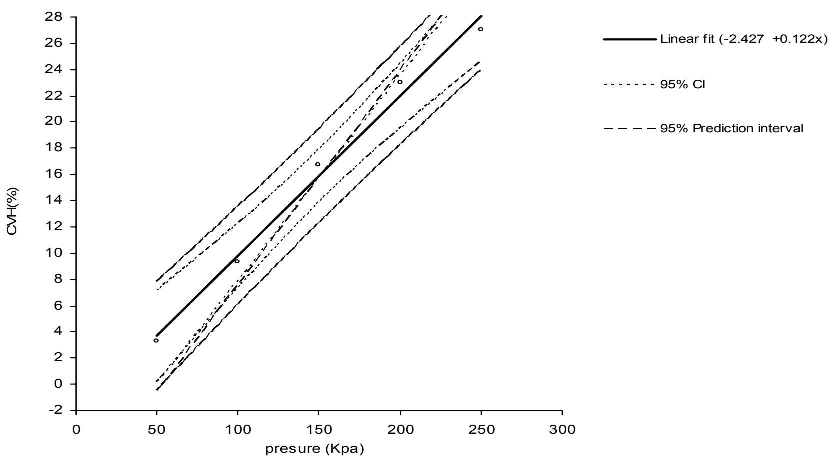

Figure 4. Hydraulic design's coefficient of variation of non pressure-compensating emitters with respect to different operating pressure of water source.

discharge variation was greater in non pressure-compensating emitters as compared to the pressure-compensating ones. Highest emitters discharge variation mean highest coefficient of hydraulic design which justify the use of the pressure compensating emitters for the micro-irrigation system design. The coefficient of variation due to hydraulic design is shown in Figs. 3 and 4 for pressure-compensating and non pressure-compensating emitters respectively. The coefficients of determination and correlation indicate the degree of accuracy. The statistical analysis based on a linear regression confirmed (R^2=0.99) of non pressure-compensating emitters on operating pressure and very less standard error (SE ≈0) around the liner fit between the 1:1 of 95% confidence and prediction intervals as compared to pressure-compensating emitters (R^2=0.71). This result further justify the use of pressure-compensating emitter and our results agree with the finding of Kirnak et al.(2004) who reported that a CV_H value of not more than 30% could yield spatial uniformities greater than 80%, which are characteristic of a standard drip systems.

Figures 5 and 6 show the combined coefficient of variations caused by manufacture as well as hydraulic design coefficients of variations in pressure-compensating and non pressure-compensating emitters respectively. Lower value of

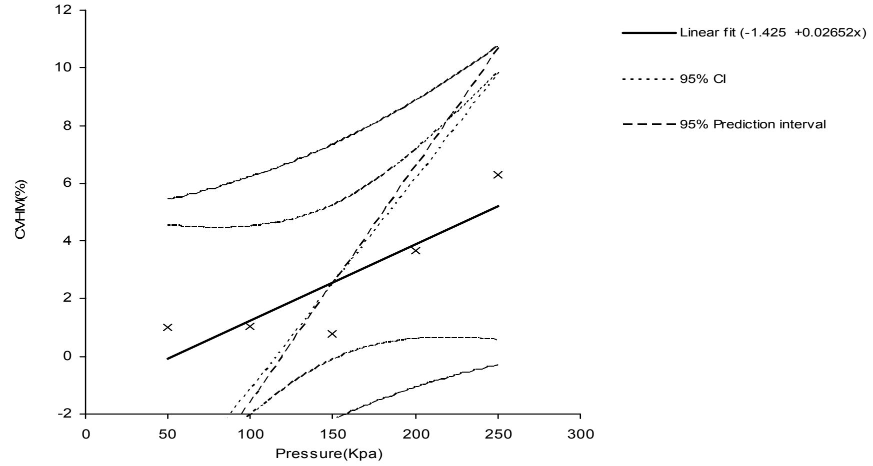

Figure 5. Total coefficient of variation of pressure-compensating emitters with respect to different operating pressure of water source.

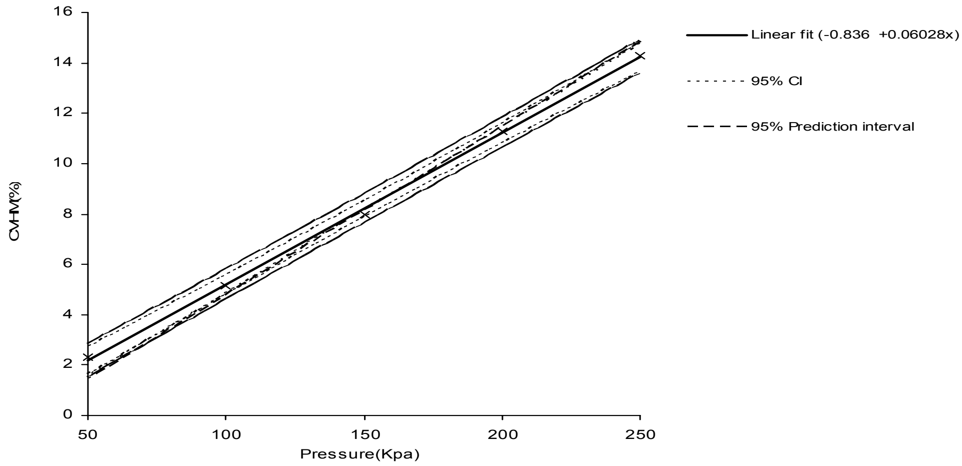

Figure 6. Total coefficient of variation of pressure-compensating emitters with respect to different operating pressure of water source.

statistical analysis from linear regression model (R^2=0.73) was observed for pressure-compensating emitters while highest value (R^2=0.99) for non-pressure-compensating emitters around the liner fit between the 1:1 of 95% confidence and prediction intervals. The manufacturer's variation of emitter flow for micro-irrigation emitters already discussed is in a range 0-20%. The cumulative effects indicate from statistical analysis, that the effect of hydraulic design will be less significant in the case when the emitters have high manufacturer's variations mainly in non pressure-compensating emitters. The result agree with Wu and Gitlin (1983), who reported that a micro-irrigation system can be designed hydraulically to maintain emitter flow uniformity within a range from 10% to 20% for the emitters flow variations .

4. Conclusion

All the performance parameters including manufacture coefficient of variation, hydraulic design coefficient of variation and their combine coefficient of variation values indicated that pressure-compensating emitters remain in the excellent category. The nominal variation in discharge of the pressure-compensating emitters is due to the ability of these emitters to overcome the effect of operating pressure and minimizing the effect of turbulence inside the laterals, which help to create equilibrium of hydrostatic pressure inside the pipe and thus deliver the same amount of discharge at each emitter. The highest correlation between non pressure-compensating emitters and source operating pressure caused high value of coefficient of variation described that non pressure-compensating emitters lack the ability to distribute the hydrostatic pressure inside the pipe uniformly and each emitters thus deliver different amount of discharge depending on operating pressure. It is recommended that the designers of micro-irrigation system should bear in mind that hydraulic design coefficient of variation is less important than manufacture coefficient of variation and it is necessary that the manufacturer should provide the detail guidelines for performance and evaluation of their products and if possible use the system.

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