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# Evaluation of Bubbler Irrigation System at Different Emission Flow Rates for Young Mango Orchard

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***ABSTRACT:*** *An experiment was conducted on evaluating performance of bubbler irrigation system under young mango plant rows at the Higher Education Commission, research station at Sindh Agriculture University, Tandojam. The experimental station possesses more than 70 mango plants, irrigated by micro and traditional irrigation methods fed by tubewell with average water static level of 9 ft below ground surface. Bubbler irrigation system was designed to irrigate 12 mango plants. The aim of study was to assess the performance of the bubbler irrigation system at different emission flow rates with an installed bubbler irrigation system to improve water distribution uniformity. The result of this study showed that the high pressure losses and the system operated on one gallon per minute flow rate of each bubbler, water distribution uniformity was low, with an average of 68 %. Other hand, comparison with emission (bubbler) flow rate was adjusted at half gallon per minute has shown high water emission uniformity of system performed with an average of 92 % distribution uniformity. The reasons for the minimum distribution uniformity of bubblers were observed at one gallon per minute emission flow and this study recommended to improve the bubbler irrigation at dissimilar flow rates.*

***Keyword:*** *Bubbler irrigation, flow rate, mango plant, water requirements*

## I. INTRODUCTION

Agriculture sector is considered as the principal and water resources consumer in the entire world. However, Majority of population is directly or indirectly involved in agriculture sector and this sector contributes about 22 % of Gross Domestic Product in the Pakistan (Agricultural Statistics of Pakistan, 2010-11) but it is still lagging and steps for better land and water conservation management practices are needed to effectively support sustainable agriculture.

In addition, agriculture could be the reason for water degradation because of the absence of proper water management, therefore, there is an urgent need for optimum use of water for agriculture and an extra emphasis should be given towards water management to prevent water pollution or deterioration of water quality.

In that high opinion, modern irrigation system such as; trickle, sprinkler and pitcher irrigation methods are considered as the most important practical and efficient for irrigation water application compared to traditional irrigation practices and application.

Bubbler irrigation system is a modified version of trickle irrigation system, Bubbler irrigation system was first time designed and introduced in orchard crops(Rawlins, 1977; Behoteguy & Thornton, 1980; Hull, 1981); Rawlins (1977) reported effective use of bubbler irrigation system in orchard fruits trees, many other researchers continued research work to improve system design that can be adopted under different aspect like as areas, weather climate, soil condition and water flow rate/ discharge on fruit trees (Behoteguy and Thornton, 1980; Hull, 1981). The system supplies water through a pumping unit, mixing chamber, mainline, sub main line, laterals and bubblers etc. The specific bubbler flow rate range between 60-240 liter per hour (Nakayama, 1986). In general, root development under trickle irrigation system is superiority constrained to the wetted soil volume by the emission points, thereby roots are concentrated near the soil surface and their length is decreased (Stevens and Douglas, 1994). The emission (bubbler) flow is controlled by pressure gauge and changing bubbler diameter. Moreover, the relatively more bubbler flow compared to short emission flow (bubblers), under bubbler irrigation system unlikely to be clogged in addition it requires minimum filtration and maintenance energy. Many researchers confirmed that the modern irrigation systems produce high yield and reducing the cost of labor and energy; similarly, modern irrigation system improves water application efficiency, uniformity efficiency and reduces water losses in irrigation practices due to evaporation and deep percolation. Moreover, a poorly designed micro irrigation system does not cover entire canopy and it is unable to provide sufficient moisture around the tree canopy hence plant remains stressed. Mirjat *et al.*, (2011) observed that the plant growth was almost similar; however, signs of leaf stress were observed under micro irrigated trees, while mango trees irrigated by traditional basin method showed no wilting sign of leaves. Local farmer reported better yield under traditional irrigated mango trees as compared to micro irrigation methods.

The Mango, (Mangifera indica L.) belonging to Family Anacardiaceae, is the most important commercially grown fruit crop in over 90 countries of the World (Evans, 2008). About 77 percent of global mango production occurs in Asia and mango cultivation is believed to have originated in South East part of the earth and at present major mango producing countries include China, Thailand, Mexico, Pakistan, Philippines, Indonesia, Brazil, Nigeria and Egypt. Among internationally traded tropical fruits, mango second ranks under fruits quantity and value. Each exporting country has its own varieties, which differ in shape, colour and flavor; Pakistan has *Sindhri, Langro, Doshehri, Chaunsa, Kali Seroli, Bagan Pali, Swarnarika and Neelum* varieties (Al-Shareed, 2013). The biggest importer of mango is the United States of America that importing an average of 1,85,000 MT annually (about 45% of the total world import volume). Mango tree is a non-drought resistant that can withstand low soil salinity level without any reduction in yield. Although the trees root zone depth is ranging between 2m to 2.5 m (MINFAL, 2005), the soil moisture is taken up by plants through their roots. Therefore, it becomes necessary that sufficient moisture remains available in the root zone and it is possible to estimate the crop water requirement for mango plant based on available literature information provided by MINFAL (MINFAL, 2005).

Mango tree is usually irrigated by traditional surface method, delivering large volume of water based primarily on farmer's experience and enhanced by the availability of free irrigation water. But other hand considering the economical importance of mango fruit, we need to enhance its production and improve the fruit quality. The mango orchard is a long term investment and a tree continues to bear fruit for longer duration than many other fruit trees. Beside other factors like soil, mango variety and environment, the water is also a key player in the mango cultivation.

The results of a study on mango plant in Pakistan on irrigation frequency have shown that the best period between irrigations intervals 7 day for young mango plant and average range of gross application depths of irrigation water 75 to 100 mm with a good quality of irrigation water (MINFAL, 2005). However, the annual water requirements demand for a mango plant may range between 500 to 750 mm and normal economic bearing life 30 to 50 years (MINFAL, 2005). In the study, to evaluate the performance of bubbler irrigation systems at emission flow rate on mango plants. Naimah, 1985 noted that, an accumulation of salts on the surface layer was higher for trickle as compared to bubbler irrigation system. As the trend continued year to year reduce mango yield due shortage of water and an abundant amount of water should be required for its irrigation, to maintain and increased mango production. As the available fresh water resources in the Pakistan are limited, it is necessary to control irrigation water through irrigation methods and soil conservation practices, such as modern irrigation systems (trickle, bubbler, Sprinkler and pitcher) for enhancing mango production.

The evaluation of bubbler irrigation method, ensure uniformly water distribution application of irrigation to avoid waste and conserve the precious water. Keeping the above fact in view this study was conducted to investigate the performance of bubbler irrigation system at different emission flow rate and used for irrigating young mango orchards.

## II. MATERIALS AND METHODS

***Description of the experimental area***

Experimental study on mango plants were conducted at the experimental station located at Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam. The experimental site is situated at the latitude of $25^0$ 25' 28" N and longitude of $68^0$ 32' 25" E; about 26 m above the mean sea level. One-year-old mango plants trees were trans planted during 2012-13 at this site on 1.5ha area having two varieties of mango were selected in this study that are suitable according to local climatic conditions and have the commercial value in local and international market. A plot measuring 19200 $ft^2$ was used in this experimental study. Mango plants were irrigated with micro irrigation systems (Drip and Bubbler Irrigation Methods) established with the financial assistant of the Higher Education Commission, Pakistan. The mango plants are irrigated from centrifugal pump/ motor, with depth of ground water at 80 ft. Soil texture is characterized as clay loam soil, with physical and chemical characteristics as summarized in Table 1.

The experimental site was selected in the second year of the HEC funded research project, the plot consists of 12 mango plant trees out of 72 mango trees with distances of 40 ft between mango to mango plants and row to row. For irrigating the young mango plant trees bubbler irrigation system, an irrigation pipe network was made and normal designed according to the guidelines provided by Keller and Karmeli, 1975; Howel et al., 1992; Nakayama and Bucks, 1986; Al-Amoud, 1999.The layout plan of bubbler irrigation system is illustrated in Figure 1.The irrigation network consists for whole plot of 2 inch main pipe line feeding 1 inch sub main pipe line, However, submain pipe line supplies to lateral (LDPE) distributing water for each mango plant tree through bubbler that discharge into a basin around mango tree.

The bubbler irrigation network has included all the necessary units and parts such as; water source, valves, filters, water meters, mixing chamber, mainline, sub main line, laterals and bubblers etc.as indicated in the network scheme sketch in Figure 1. In experimental, the mango plants irrigated with water from a ground water in the site with suitable water quality as present in Table 1. The experimental area climate is characterized by high temperature in the May to August (summer season) with short amount of rain fall occurred as shown in the climatic data (Table 2). The land preparation, irrigation scheduling and other agro-chemical practices for young mango plant were followed as per guidelines by MINFAL (2005).

The irrigation scheduling is based on the soil moisture depletion. In this study, 50% soil moisture depletion was fixed and next irrigation was applied when soil moisture deficit attained this criterion (MINFAL, 2005). Soil samples were collected at the vicinity of emission point under bubbler irrigated plots and soil moisture contents were determined. Soil moisture content was determined by oven drying the soil sample for 24 hrs at a temperature of 105 $^{0}$C and was calculated by using appropriate equation. Tensiometers were installed to measure the soil moisture deficit. Once soil has attained the desired deficit, irrigation was applied to bring it at the field capacity. The irrigation depths were calculated using equations given by Soomro *et al.*, 1999; Soomro *et al.*, 2001:

$$D = \frac{\mathrm{SMD}}{100} \mathrm{x\ pb\ x\ dr} \qquad (1)$$

$$SMD = \theta_f - \theta_o \qquad (2)$$

$$\theta = \frac{(W_w - W_d)}{W_d} \mathrm{x}\ 100 \qquad (3)$$

Where,

D = Depth of water required (cm)

SMD = Soil moisture deficit level

pb = Bulk density (grams cm$^{-3}$)

$\theta_o$ = Moisture content at 50 % SMD

$\theta$ = Moisture content on dry weight basis (%)

$W_w$ = Wet weight of soil (g)

$W_d$ = Oven dry weight of soil (g)

Water was delivered to irrigation plots through motor pumps, installed to maintain required Pascal operating pressure throughout the bubbler irrigation network system. The water delivery to system was installed using pipes selected to minimize friction losses and ensure uniformity distribution in all selected plots of research project. Mango plant trees in bubbler irrigation plot was designed to receive water from 1 bubbler at a flow rate of 1 gallon per min. The system operating pressure was monitored throughout the experiment using pressure gauge installed at main pipe line of the system in pumping station.

For comparison purpose, bubblers at a flow rate of 1 gallon per min in some experimental plot were adjusting by 1bubbler at a flow rate of 0.5 gallon per min. Evaluation the performances of bubbler irrigation systems were first made volume of water under each bubbler was measured and emission uniformity of water application was determined. The containers were placed underneath each emission point and water flowing through a bubbler, for a given time, was collected. After a given time, interval, the flow was disconnected and the containers were removed. The volume of water collected in each container was measured using a graduated cylinder. The recorded volume was divided by time to yield the discharge at each bubbler. The measured discharge was used to calculate the uniformity coefficient, coefficient of variation (Cv) and distribution uniformity were also calculated (Table 5) using the equations given by ASAE, 2002; Mosh, 2006; Mirjat*et al.*, 2010; Tagar *et al.* 2012 and the recommendations of Killer and Bliesner, 1990.

$$C_u = 100 - \left( 80 - \frac{S_d}{V_{avg}} \right) \qquad (4)$$

$$Cv = \frac{\sigma}{V_{avg}} \mathrm{x}\ 100 \qquad (5)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (V_{LQ} - V_{avg})^2}{n}} \quad (6)$$

$$D_u = 100 \left( \frac{V_{LQ}}{V_{avg}} \right) \quad (7)$$

Where,

$C_u$ = Uniformity coefficient (%)

$S_d$ = Standard deviation of observations

$V_{avg}$ = Average volume collected

σ = Standard deviation

$Cv$ = Uniformity variation (%)

$V_{avg}$ = Average volume collected.

$V_{LQ}$ = Average of the lowest ¼ volume of water relaxed

$D_u$ = Distribution uniformity (%)

$V_{LQ}$ = Average of the lowest ¼ volume of water relaxed

$V_{avg}$ = Average volume relaxed

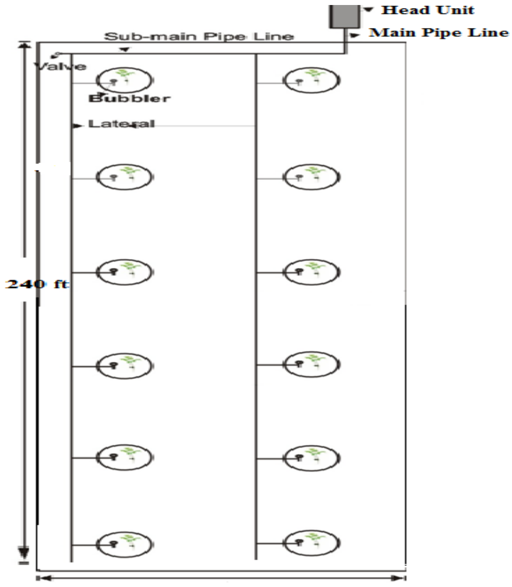


**Figure 1** Bubbler Irrigation System Layout

**Table 1.** Soil and water analysis results before experiment

| **Soil Characteristics** | | **Values** |
|---|---|---|
| **Physical Properties** | | |
| Sand (%) | | 41.4 |
| Silt (%) | | 28.3 |
| Clay (%) | | 30.3 |
| Texture | | Clay Loam |
| Bulk Density | | 1.17 g $cm^3$ |
| Infiltration Rate | | 8 mm $hr^{-1}$ |
| **Chemical Properties** | | |
| Soil pH | Depth at 0-15 cm | 7.9 |
| | Depth at 15-30 cm | 7.85 |
| | Depth at 30-45 cm | 7.86 |

| | | |
|---|---|---|
| Soil $EC_e$ (dS/m) | Depth at 0-15 cm | 1.06 |
| | Depth at 15-30 cm | 0.86 |
| | Depth at 30-45 cm | 0.69 |
| Sodium Adsorption Ratio (SAR) | Depth at 0-15 cm | 5.6 |
| | Depth at 15-30 cm | 5.6 |
| | Depth at 30-45 cm | 6.5 |
| **Water Characteristics** | | |
| pH | | 7.7 |
| EC (micro-S/cm) | | 1361 |
| SAR | | 6.72 |

**Table 2.** Average weather parameters during the period of experiment

| Month | Temperature C° | | Relative Humidity % | | Pan Evap. 24hrs (mm) | Rain Fall (mm) |
|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | | |
| September, 2012 | 26.65 | 34.25 | 62.67 | 86.57 | 6.88 | 4.71 |
| October, 2012 | 21.55 | 35.63 | 43.33 | 87.23 | 5.27 | 00 |
| November 2013 | 16.37 | 30.95 | 42.13 | 80.40 | 3.53 | 0.08 |
| December, 2012 | 12.50 | 25.50 | 52.10 | 78.90 | 3.64 | 00 |
| January, 2013 | 10.25 | 24.82 | 43.47 | 84.23 | 3.41 | 1.00 |
| February, 2013 | 12.87 | 23.72 | 46.43 | 70.50 | 3.72 | 3.50 |
| March, 2013 | 16.92 | 33.77 | 38.57 | 76.53 | 6.09 | 00 |
| April, 2013 | 22.25 | 36.20 | 38.57 | 68.63 | 7.29 | 00 |
| May, 2013 | 27.37 | 42.03 | 32.33 | 64.03 | 10.40 | 00 |
| June, 2013 | 29.37 | 38.13 | 48.80 | 73.03 | 10.27 | 0.17 |
| July, 2013 | 29.65 | 37.53 | 58.33 | 81.03 | 9.95 | 00 |
| August, 2013 | 28.08 | 35.03 | 65.50 | 88.20 | 7.75 | 5.99 |
| September, 2013 | 26.63 | 35.60 | 57.13 | 84.60 | 7.39 | 0.75 |

## III. RSEULTS AND DISCUSSIONS

Evaluating the performance of bubbler irrigation system at one gallon per minute emission (bubbler) flow, was calculated noticeable variations in distribution uniformity of water in young mango plant lines as shown in Figure 2 and 3, and details of each bubbler flow under bubbler system are presented in Table 3.It is also clear from the Table 3that there is a decrease in emission flow with length of lateral of the system (i.e. mango plant at the end less water received), this is possibly due to decrease in pressure in lateral line of system caused by friction loss. Data revealed that the co-efficient of variation for lateral 1 and lateral 2 were 21.33 and 23.53, respectively. Likewise, the distribution uniformity of lateral 1 and lateral 2 were 73 % and 71 %, respectively at one gallon per minute emission flow rate. As a result, the system was tested that low distribution uniformity of system was 68 as shown in Table 4, these values may be below the accepted range of distribution uniformities of system recommended by ASAE and ASABE standard (ASAE, 1987 and ASABE (1999).

Results of half gallon per minute of emission (bubbler) flow rate of lateral lines performance was shown an improved distribution uniformity of water for young mango plants, as shown in Figure 3. The horizontal trend line of emission flow distribution shown (Figure 4 and 5) and Table 4 indicates even distribution of irrigation water to all plants in both line with an emission uniformity ranging from 92.52 % to 93.75 %, and co-efficient of variation are varied from 4.677 to 5.573 respectively. Al-Amoud (2008) who reported the uniformity of distribution of bubbler system was low with drip irrigation system which is in contradiction to our results. These results suggest that the system can be rated from good to excellent i.e. satisfactory as mentioned by ASABE (1999).

The performance of bubbler system was low due to inadequate design under one gallon per minute emission flow. The bubbler discharges an abundant amount of water; its total flow for each bubbler under plant basin is one gallon per minute which is more than the capacity size of the lateral diameter. Results revealed that high friction loss occurred in which turn reduces the flow in further sections on laterals. Bubbler flow rate is half gallon per minute on the other hand marked a maximum distribution uniformity of system under both lateral which is within the capacity of the lateral size. To sustain the present bubbler irrigation system, the existing bubblers should be adjusted at half gallon per minute emission flow exceed. The existing bubbler irrigation system may be also adjusted at half gallon per minute emission flow to reduce friction losses.

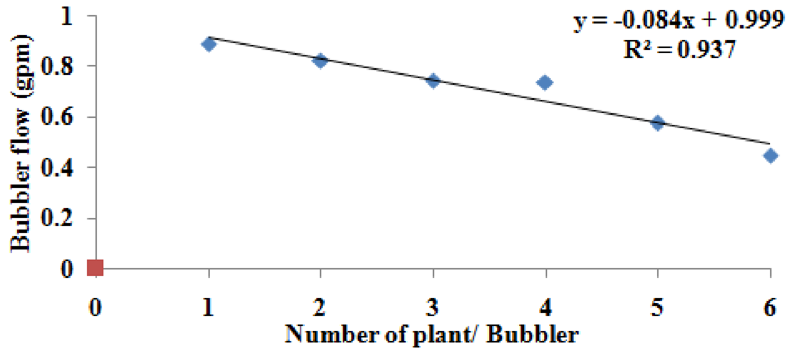


**Figure 2.** Water distribution fluctuations through first bubbler lines and trend line at one gallon per minute emission flow

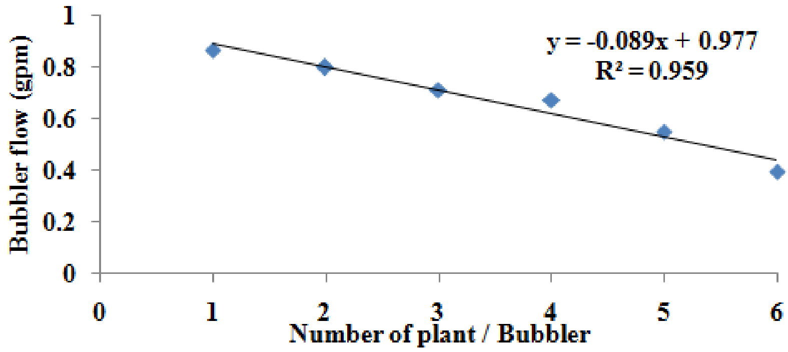


**Figure 3.** Water distribution fluctuations through second bubbler lines and trend line at one gallon per minute emission flow

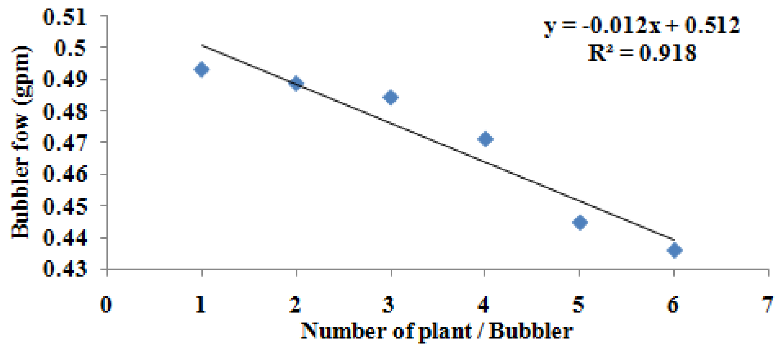


**Figure 4.** Water distribution fluctuations through first bubbler lines and trend line at half gallon per minute emission flow

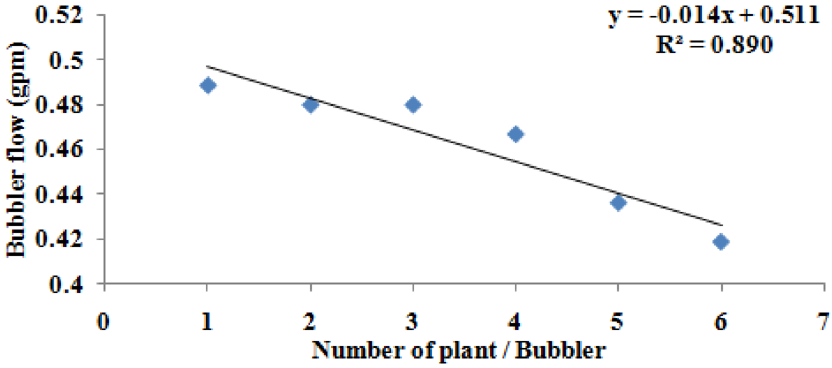


**Figure 5.** Water distribution fluctuations through first bubbler lines and trend line at half gallon per minute emission flow

**Table 3.** Bubbler discharge at different emission flow rates

| **Bubbler No.** | **Discharge rate** | | **Bubbler No.** | **Discharge rate** | |
|---|---|---|---|---|---|
| | **System run at one gallon per minute** | **System run at half gallon per minute** | | **System run at one gallon per minute** | **System run at half gallon per minute** |
| | **Lateral 01** | | | **Lateral 02** | |
| $L_1B_1$ | 0.889 | 0.493 | $L_2B_1$ | 0.863 | 0.489 |
| $L_1B_2$ | 0.823 | 0.489 | $L_2B_2$ | 0.797 | 0.480 |
| $L_1B_3$ | 0.744 | 0.484 | $L_2B_3$ | 0.709 | 0.480 |
| $L_1B_4$ | 0.735 | 0.471 | $L_2B_4$ | 0.669 | 0.467 |
| $L_1B_5$ | 0.577 | 0.445 | $L_2B_5$ | 0.550 | 0.436 |
| $L_1B_6$ | 0.445 | 0.436 | $L_2B_6$ | 0.392 | 0.418 |
| Total | 4.214 | 2.818 | Total | 3.981 | 2.770 |
| Average | 0.702 | 0.470 | Average | 0.663 | 0.462 |

Note: L is lateral and B is Bubbler

**Table 4.** Minimum discharge, Average discharge, Standard deviation, Coefficient of variation, Uniformity coefficient and Distribution uniformity of existing system

| Sr. No | Min. discharge $q_m$ (lit/hr) | Av. discharge $q_{avg}$ | $\Sigma(q - q_{av})^2$ | Standard deviation σ | Coefficient of variation (Cv) | Uniformity coefficient (Cu) | Distribution uniformity (Du) |
|---|---|---|---|---|---|---|---|
| System run on one gallon per minute of emission flow | | | | | | | |
| Lateral 1 | 101.000 | 159.500 | 6943.5 | 34.018 | 21.328 | 82.937 | 72.727 |
| Lateral 2 | 89.000 | 150.667 | 7545.3 | 35.462 | 23.537 | 81.171 | 71.018 |
| Entire System | 89.000 | 155.083 | 8734.7 | 26.979 | 17.397 | 86.083 | 67.706 |
| System run on half gallon per minute of emission flow | | | | | | | |
| Lateral 1 | 99.000 | 106.667 | 149.33 | 4.989 | 4.677 | 96.258 | 93.750 |
| Lateral 2 | 95.000 | 104.833 | 204.83 | 5.843 | 5.573 | 95.541 | 92.528 |
| Entire System | 95.000 | 105.750 | 181.94 | 3.894 | 3.682 | 97.054 | 92.356 |

## IV. CONCLUSIONS AND RECOMMENDATIONS

It is evident from the above results that the evaluated performance of bubbler irrigation system at one gallon per minute emission flow was inefficient for young mango plants as compared to same bubbler irrigation system adjusted on half gallon per minute emission flow. The present study concluded that half gallon per minute emission flow of system of each bubbler with proper design and management could satisfy water needs for young mango plants.


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