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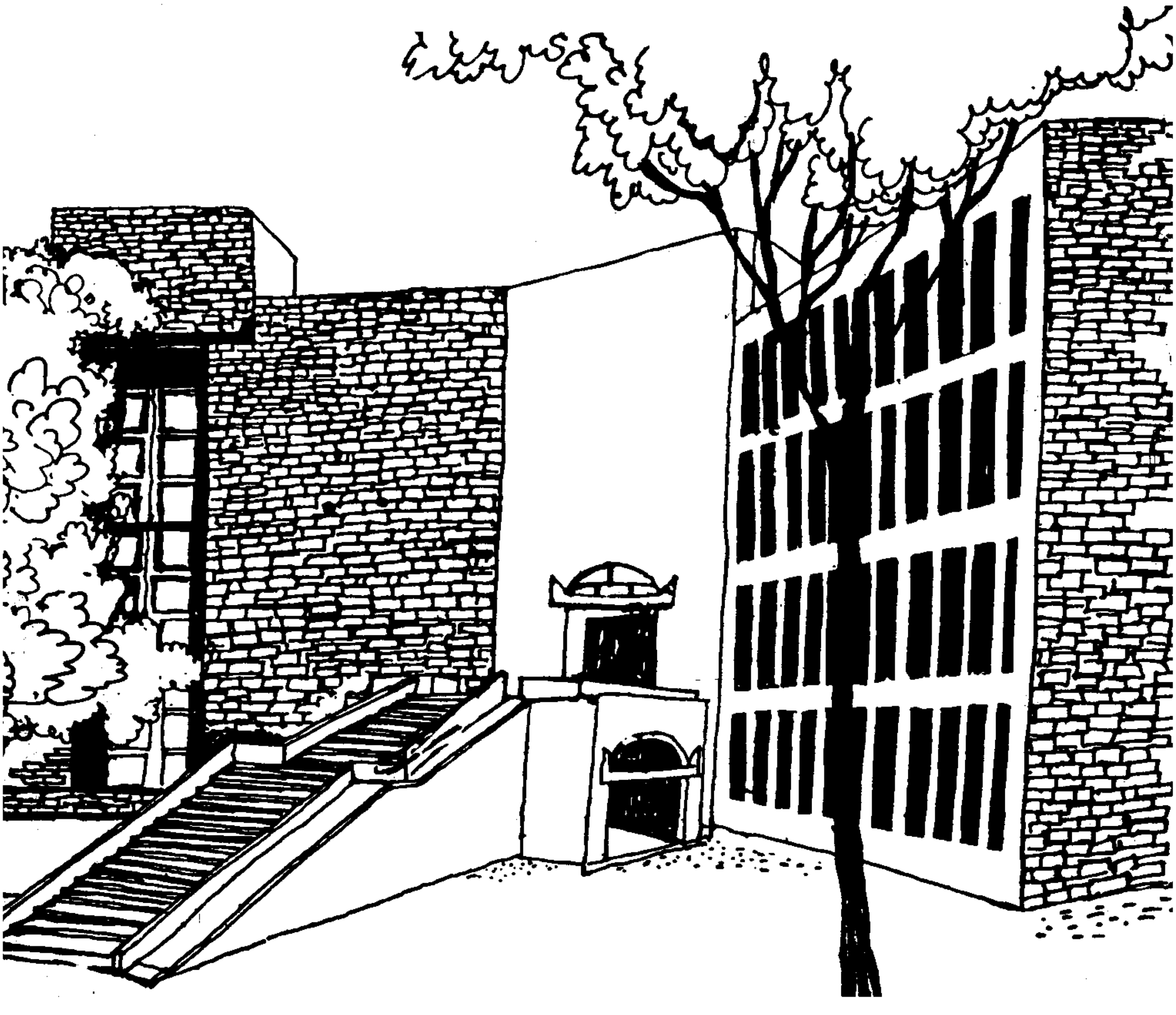

A WATERING SYSTEM FOR POTTED PLANTS

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Abstract

This paper deals with design of a watering system for a large number of potted plants that form part of a landscape. Installation of the system was motivated by a desire to save labour, time and water. The system now in operation consists of delivery rings to which are attached large number of microtube emitters. Each emitter takes water to one pot, each ring caters to a cluster of 20 to 25 pots. More can be added when needed.

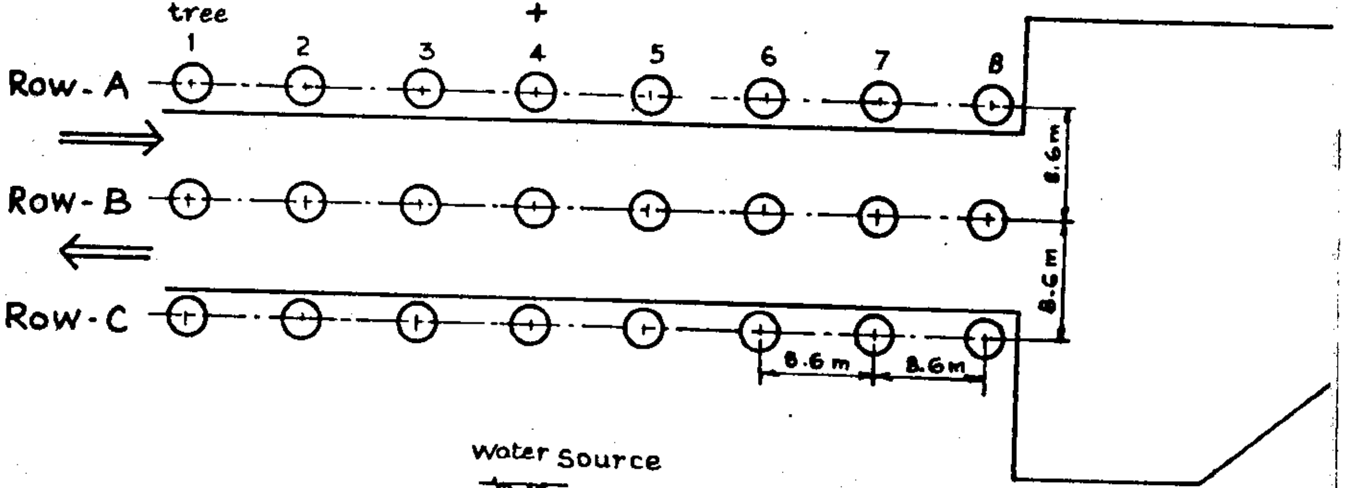
Flow rate from emitters can be varied by changing the length of tube. Cost of the system was Rs.5800 and it takes care of about 600 potted plants. Presently no provision has been made for fertigation or filtering, which is proposed to be added later.

Introduction

Along two-lane, short approach drive to the main complex of Indian Institute of Management, Ahmedabad, there are three rows of <u>peltophorem</u> trees, two on the side and one in the centre (**figure 1a**). There are eight trees in each row spaced 8.6 m apart. Rows too are 8.6 m apart. Some 20 to 25 ornamental potted plants are usually placed in concentric rings, around the base of each tree. Thus, there are a total of 500 to 600 pots, in 24 clusters. Trees have developed a nearly closed canopy. Pots, therefore, remain mostly under shade.

Watering the pots, done manually, is a time consuming and expensive task. It takes nearly two to three hours every day. Moving a 50 m long hose from cluster to cluster is inconvenient. Some water is wasted while moving the hose between clusters. Hose often comes in the way of passing vehicles. A positive side of the present method is that the

Fig. 1(a) : The site



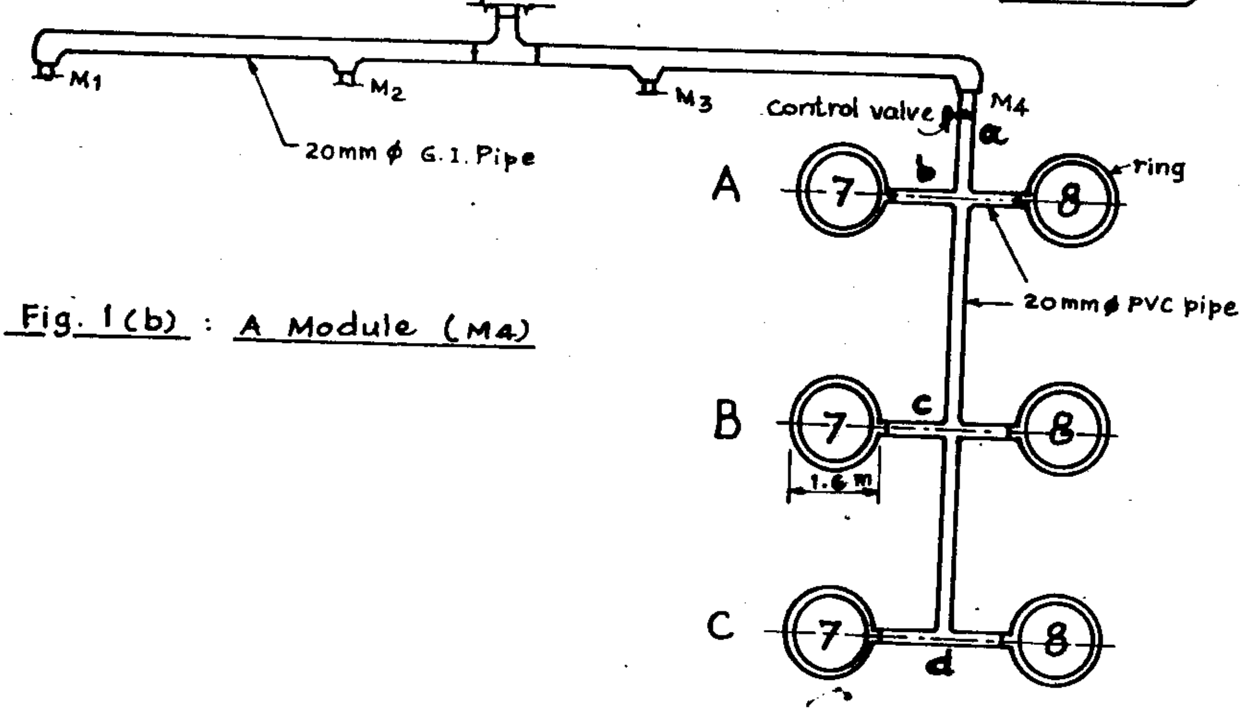


Fig. 1(b) : A Module (M4)

Fig. 1(c) : Ring Emitter A-8

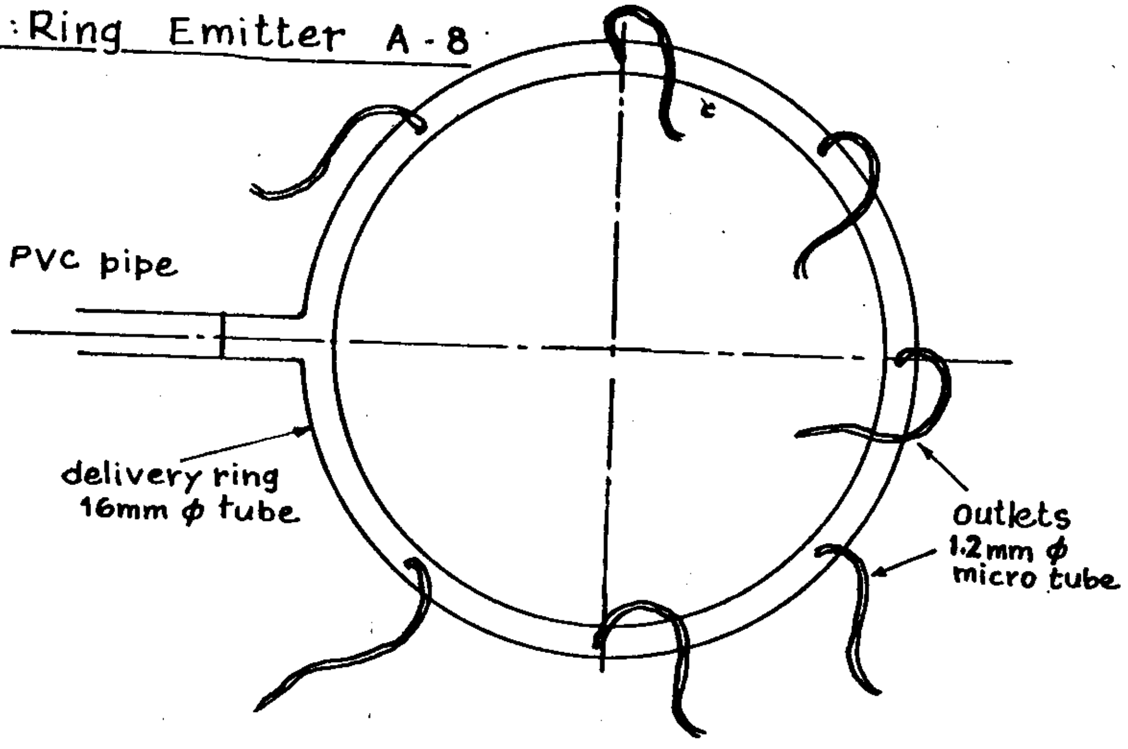


Figure 1: System Layout

amount of water to be given to each plant and the frequency can be judged by the gardener individually.

In view of the negative aspects cited above, it was decided to install a micro-watering system. Accordingly, a system using ring emitters, has been installed and is now in use. It takes just 5 to 7 minutes to water all the 600 plants. The cost of material used in the system was Rs.5800.

In this paper we describe the system and report its operating characteristics. Such a system could be useful in other situations such as green houses, large commercial nurseries campuses, industrial estates and in residences.

User Requirements

Estate Department of the Institute stipulated the following design requirement.

(a) relieving the gardener of daily task of watering should be the main objective, so that he can devote to more creative tasks;

(b) cost of new system should be justifiable by the savings, and it should be easy to maintain;

(c) it should lend itself to upgradation at a later date, such as installation of timer control;

(d) each cluster has a mix of different species with differing water requirement; if possible, there should be a way to apply different amount of water to different pots simultaneously.

Concept Design

The pressure head available at site varies during the day from 1 kg/sq. cm to 2 kg/sq. cm. Most of the commonly available emitters such as drippers, micro-sprinklers, microtubes etc. can thus be used without an additional pump. However, the water quality at the Institute is poor. It contains high levels of salts. Drippers are therefore likely to have clogging problem.

It is still not easy even in big cities like Ahmedabad to procure small quantities of microwatering components.

In view of this, it was decided not to use drippers. Instead, it was proposed to use microtubes to take water to each pot individually. Microtubes are used very commonly in automatic watering systems for potted plants in green houses.[1] A user can procure a large roll of microtube and keep in store for future use. Clogging of microtube emitters generally takes place near the exit tip. In case of severe clogging tip could be clipped or the entire tube replaced.

Normally, the starting point in designing a watering system would be estimation of water requirement. Our review of literature showed that very little attention has been paid to landscape irrigation. We found no work that deals with water requirement of potted plants that form part of a landscape. Beccard and Hurst [2] whose work related to landscape also stated, "we are not aware of any studies in which the actual water use of trees, shrubs, or ground cover, typically used in landscapes, has been measured in a landscape setting."

In the present work, therefore, we have concentrated on designing a delivery system that will meet some of the user stipulations.

Ring Emitter and its Hydraulics

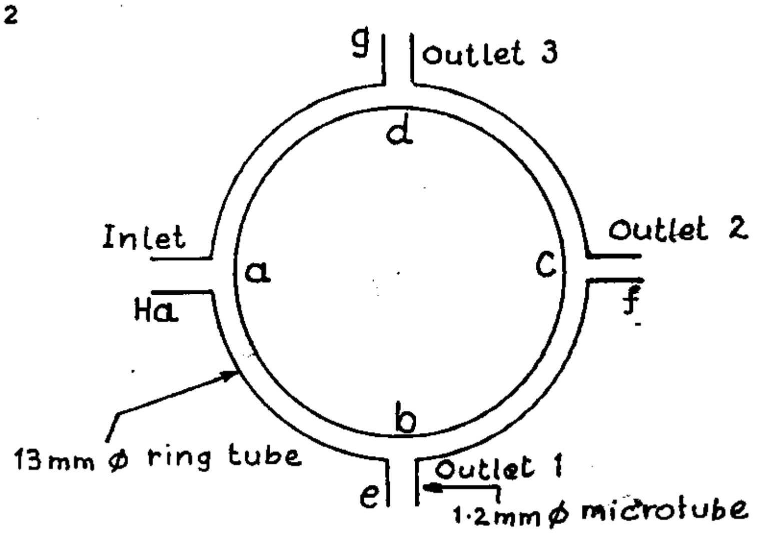
Emitter

What has been termed here as 'ring emitter' is an assembly, consisting of a ring to which are attached several microtube outlets. A 5 m long segment of pipe, is made into a ring with ends attached to a tee. Microtube outlets are attached to this ring. Details of one of the emitters (A-8) are shown in **figure 1(c)**. Outlets are made of 1.5 mm dia microtube. Exit end of microtube is placed on the top surface of the pot and loosely fastened to the stem of the plant. Rings are laid level on the ground. These can also be put just below the surface. Each ring has 20 to 25 outlets which carry water to individual pots. More outlets can be added or some plugged, when necessary. All the 24 emitters are identical.

Hydraulics

Consider three outlets placed symmetrically (at 90°, 180° and 270°) around the ring from the inlet as shown in **figure 2**. Given the pressure head (Ha) at node a, it is desired to compute discharge from each of the three outlets. The iterative procedure used here is outlined below. Frictional losses in all segments are calculated using William Hazen (WH) correlation. Minor losses are calculated using relevant loss coefficients.

Figure 2



William-Hazen correlation (with C = 150)

$$H_f = 15.27 \frac{q^{1.852}}{d^{4.871}} L \qquad (1)$$

Minor losses,

$$h_m = K \frac{q^2}{2a^2} \qquad (2)$$

where

H head
hf frictional head loss

hm	minor losses
hl	total losses
q,Q	discharge
d	diameter
L	length
a	cross section area

Iterative Procedure

Step-1: Assume an arbitrary value for flow into the ring (say Q_a) at a. Flow into branches, a-b and a-d will be Qa/2 due to symmetry. Thus,

$$q_{ab} = \frac{Qa}{2}$$

Step-2: Using this q_{ab}, compute head loss (h_{lab}) in segment a-b using WH correlation and relevant minor loss term. Head at node, B, is then computed.

$$Hb = Ha - h_{lab}$$

Step-3: Using this Hb, compute discharge (q1) through the first outlet which is open to atmosphere.

Step-4: Flow in segment b-c can now be computed.

$$q_{bc} = \frac{1}{2} Q_a - q_1$$

With q_{bc} known, head loss in segment bc can be computed. This enables one to get Hc and then q2.

Step-5: Continuity and symmetry require that

$$Q_a = 2q_1 + q_2$$

If the computed values (q1 and q2) do not meet this requirement, steps 1 to 5 are repeated, using a new value of Q_a. This new value is set equal to $2q_1 + q_2$.

The above procedure converges rapidly and is easily generalised for larger number of outlets. **Tables 1 and 2** show the computed values of discharge with 10 m operating pressure head at inlet. As seen, the computed discharge rates at 10 m head are 14 to 15 lph. This will reduce/increase if the length of microtube is increased/decreased. Though the discharge is higher than that of pot drippers, it was decided to use the microtubes in view of their properties stated earlier.

Our aim here was to get an estimate of the discharges likely from ring emitters with varying number of outlets. Furthermore, to determine the effects of head and size of microtube (length and dia) on discharge and uniformity.

The iterative procedure outlined above enables us to do so. It must be kept in view, however, that simplification in the procedure was result of the assumed symmetry. A more complex procedure will be needed if the outlets are not identical and not placed at uniform interval.

There is another important aspect. As the number of outlets is increased on a ring of given perimeter, the roughness of the ring tube will increase altering its flow properties. This aspect has been ignored here.

System Layout

Figure 1 (a), (b), (c) show the details of site and the system. System consists of four modules (M1, M2, M3, M4). Each module has its own control, and caters to six clusters of pots. For instance, details of one module (M4) are shown in **figure 1(b)**. This module supplies water to pot clusters 7 and 8 of all three rows. A 20 mm dia rigid PVC pipe (ad) constitutes the sub-main. Junctions--b,c,d--provide take off to the clusters as shown. The section between junctions and the entrance to the ring is also 20 mm rigid PVC pipe.

Table 1
Discharge from Ring Emitter Outlets
(Computed)

No. of outlets	Inflow into ring (lph)	Mean Discharge from outlets (lph)	Absolute maximum deviation (% of mean)
1	15.808	15.808	0.00
3	47.421	15.807	0.00
5	79.031	15.806	0.01
15	236.977	15.799	0.05
25	394.629	15.785	0.13
35	551.831	15.767	0.25
45	708.441	15.743	0.39

Note: Outlets identical (L = 0.5 m, dia 1.2 mm) and placed at equal interval around the ring. Pressure head at inlet 10 m.

Minor losses ignored.

Table 2
Discharge from Ring Emitter Outlets
(Computed)

No. of outlets	Inflow into ring (lph)	Mean Discharge from outlets (lph)	Absolute maximum deviation (% of mean)
1	14.750	14.750	0.00
3	44.249	14.750	0.00
5	73.745	14.749	0.01
15	221.142	14.743	0.05
25	368.298	14.732	0.12
35	515.089	14.717	0.22
45	661.398	14.698	0.34

Note: Outlets identical (L = 0.5 m, dia 1.2 mm) and placed at equal interval around the ring. Pressure head at inlet 10 m.

Minor losses included.

At present, no filter has been provided. Nor has provision been made for fertigation. These features will be added gradually. So also, eventually, perhaps a timer control.

Test Stand

In order to compare the analytically computed discharge with actual measurements, a prototype was first made and tested. The test assembly consisted of a ring emitter with a control valve and a Bourden type pressure gauge attached on the upstream side. The supply was taken directly from the main. Sections of microtube were cut randomly from the roll to make the outlets. Ends were kept straight. One end was inserted into the ring projecting about 5 mm inwards. Holes were made with a nylon punch. The other end of the tube was led to graduated vessels for collection of water. Tests were made outdoors during the day when temperatures ranged between 35-40°C.

Since the pressure head available at site, varied from 0.5 to 2 kg/sq cm, discharge was determined under this range of pressures. Tests were also made using different length of microtube (50-200 cm) in order to see the degree to which flow rate could be varied by varying the length. Microtube of only one size was tested, whose diameter was stated to be 1.5 mm by the manufactures. On actual measurement, however, the diameter was found to be 1.2 mm. Three replications of each test were made.

Ring with One Outlet

Discharge and Head : **Table 3** shows the discharge measured at different heads from a ring emitter with one outlet. The table also shows discharge computed analytically. The two sets of values are quite close. The difference is negligible up to 15 m head. But at 20 m, the difference is about 4%.

It was found that when there is only one outlet the losses in the ring are negligible. Under this condition therefore, the results obtained here should be comparable to some others reported in literature.

Khatri et al[3] studied the hydraulics of microtube emitters and developed empirical head-discharge correlations for laminar, transitional and turbulent regions. Babel et al[4] made a similar study and also developed correlations. Discharge computed using their correlations are also shown in **table 3**. The results from both of these are also very close to the measured values. These correlations could therefore be also used in designing. **Figure 3** shows the above data graphically.

Table 4 shows the values of discharge for microtube of different length. **Figure 4** shows the same data graphically. The difference between the observed and the analytically computed values differ by about 10% when the length of tube is longer. The values obtained from Khatri et al as Babel et al also show large variation from the observed values.

When length was increased from 50 cm to 200 cm (four times) discharge reduced by a factor of 2.28. This is desirable feature. It will make it possible to provide different amount of water to pots in the same cluster.

Ring with Three Outlets

As stated earlier, each ring has 20 to 25 outlets. It is necessary to get an idea of uniformity of discharge between outlets. However, it was difficult to arrange simultaneous measurement of such a large number. The computations were checked against measurements with a ring having three outlets placed at 90°, 180° and 270° in the delivery ring.

Table 3
Discharge under Different Heads

Head (m)	Measured discharge (lph)	Reynold's number	Discharge computed per		
			Khatri et al	Babel et al	Hazen-William Equation
5	9.78	2998	10.76	9.57	10.17
10	15.28	4344	14.98	14.78	14.73
15	18.82	5397	18.64	18.25	18.31
20	22.23	6293	21.76	21.20	21.35

Note: (a) Ring emitter with one outlet (1.2 mm dia 50 cm length)
(b) Computed values are based on correlations for transitional region

Table 4
Length of Tube and Discharge

Length of outlet (cm)	Measured discharge (lph)	Reynold's number	Discharge computed per		
			Khatri et al	Babel et al	Hazen-William Equation
50	15.28	4344	14.98	14.78	14.73
100	9.61	3095	11.32	10.81	10.5
150	9.20	2516	9.14	9.27	8.53
200	6.65	2166	7.86	8.32	7.34

Note: (a) Ring emitter with one outlet (1.2 mm dia)
(b) Head constant at 10 m

Figure 3

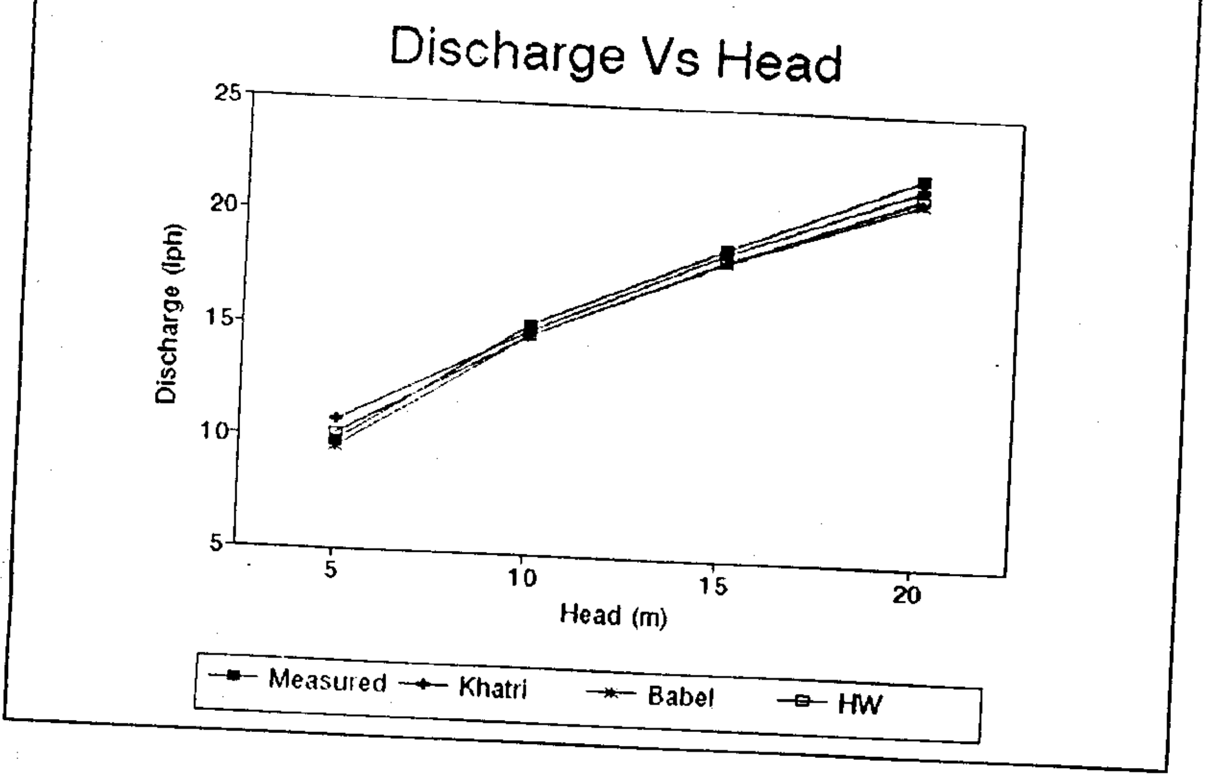


Figure 4

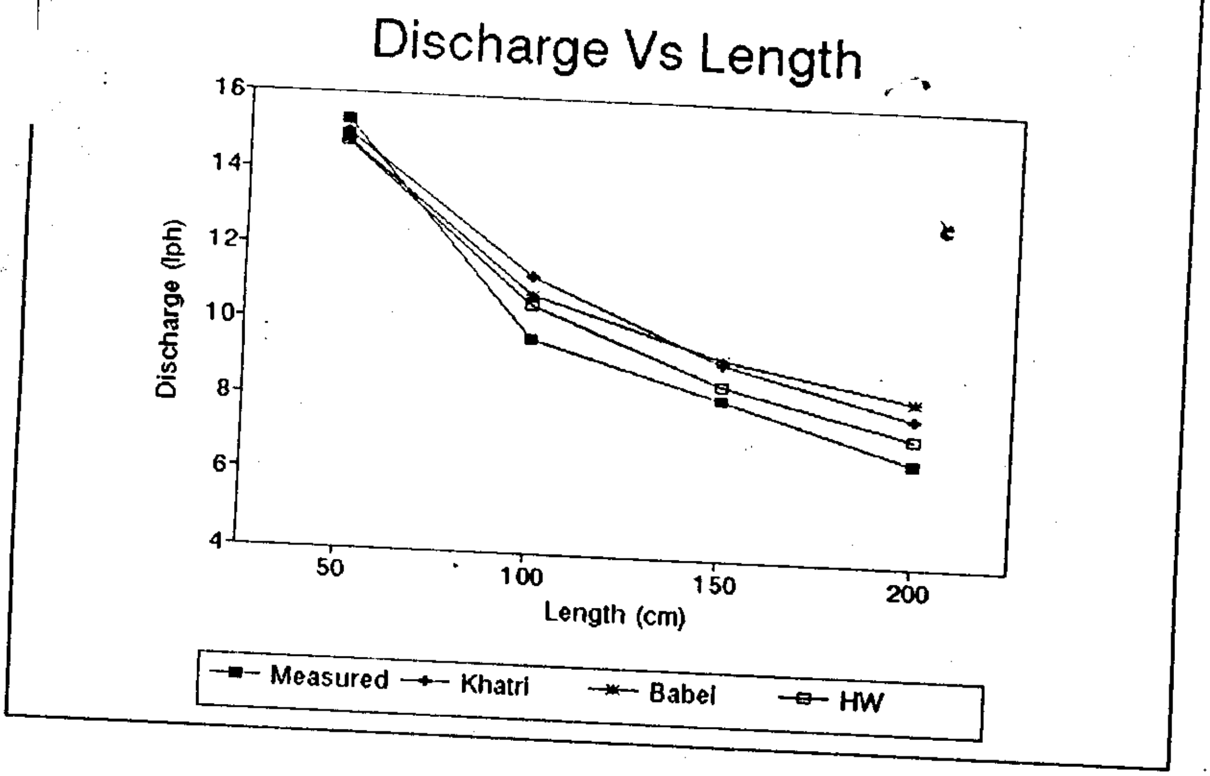


Table 5 shows the results. It is seen that discharge from outlet # 1 and 3 is virtually identical. Discharge from outlet # 2 is smaller than that of outlets # 1 and 3. The difference of course is very small.

Table 5
Ring Emitter with Three Outlets
Discharge under Different Heads

Head (m)	Discharge (lph)					
	Outlet # 1		Outlet # 2		Outlet # 3	
	Measured	Computed	Measured	Computed	Measured	Computed
10	14.92	15.807	14.63	15.80	14.82	15.807
16	19.04	20.373	18.90	20.373	19.01	20.373
20	22.11	22.982	21.80	22.981	22.11	22.982

Note: Outlets made of microtube (1.2 mm dia, 50 cm length)

Summary and Conclusions

A watering system, consisting of delivery rings with a large number of microtube outlets has been devised to cater to a large number of potted plants placed in clusters. The present systems cater to about 600 pots.

Cost of the system was Rs.5800. Its immediate benefit has been reduction in labour and time otherwise needed in looking after the plants.

Number of outlets in a ring can be varied as per need. Flow rates from the outlets can be varied by changing the length of microtube. This enables one to apply water at different rates to pots in the same cluster when necessary.

The discharges from outlets obtained analytically do compare well with the measurements, suggesting that William Hazen correlation and those suggested by Khatri et al could be used for design.

However, the computations presented here were for simpler case of identical, symmetrically placed outlets. Case where outlets are different in geometry and placed at varying intervals will need to be studied. So also the effect of density of outlets on the flow characteristics of delivery ring.

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