**Pakistan Journal of Life and Social Sciences**
www.pjlss.edu.pk

RESEARCH ARTICLE

# Redesigning of Drip Irrigation System Using Locally Manufactured Material to Control Pipe Losses for Orchard

Qaiser Javed[1], M. Arshad[1], Allah Bakhsh[1], Aamir Shakoor[1,*], Zia A. Chatha[2]and Ijaz Ahmad[3]
[1]Department of Irrigation and Drainage, University of Agriculture, Faisalabad, Pakistan;
[2]Faculty of Agricultural Engineering and Technology, University of Agriculture, Faisalabad, Pakistan
[3]Water and Sanitation Agency (WASA), Faisalabad, Pakistan

***ARTICLE INFO***
Received: Dec 21, 2013
Accepted: Nov 18, 2014
Online: Jan 18, 2015

***Keywords***
Designing of drip irrigation system
Drip irrigation
Losses in PVC pipe

***Corresponding Author:**
aamirskr@yahoo.com

**ABSTRACT**

Land and water are two important factors, which are required for agricultural development and strong economy of a Pakistan. Pakistan is facing the problem of water scarcity and the demand of water for irrigation is also increased due to mounting demand of food and fiber. This challenge could be achieved by adopting the water saving techniques or method, such as drip irrigation system. The performance and efficiency of the drip irrigation system depends on the best designing of the system. The objective of the study was to redesign the already installed irrigation system to make it more efficient. For that purpose the research was performed on Guava orchard, located at Taqi Abad, a village in Chiniot. In redesigning, the spacing of laterals were decreased from 5 to 4.57m while and sub-main decreased 4.88 to 4.5m and pipe losses were compared at different discharge. So, the head losses were decreased for laterals from 1.76 to 1.38m and for sub-main from 0.81 to 1.16m. The installation cost was also reduced from 1.28 to 1.136 million rupees. It was concluded that losses occurred were more when discharge was more and pipe diameter was less or vice versa.

## INTRODUCTION

Agriculture has greater contribution and plays a major role towards Pakistan's economy. Moreover, increasing demand of water for agriculture due to increasing food demand is adversely affecting the performance of agriculture sector. In 1950, Pakistan had approximately 5133m$^3$ of water per capita which was reduced to 1210m$^3$ in 2010 and further reduced to 1050m$^3$ in 2012. It was estimated that this amount would further decrease to 600m$^3$ in 2025 (PAS, 2006). Water productivity for wheat is 0.6 kg/m$^3$ in Pakistan as compared to India and California which is 1.5 kg/m$^3$ (Qureshi, 2011). It is important to enhance the water productivity for food security, which is one of the major issues in Pakistan.

According to World Bank report, Pakistan falls in the category of water deficit country due to its low water availability. Therefore, it is dire need of the time to enhance the water productivity and food security that is needed to be filled by adopting the way of "more crop per drop". This goal can be achieved by adopting water saving irrigation method like High Efficiency Irrigation System (HEIS). The drip and sprinkler irrigation system were working more efficiently in the area where traditional irrigation methods do not work satisfactorily, for example in desert and hilly areas (Bhutta and Azhar, 2005).

Drip irrigation has more benefits over traditional surface irrigation method due to its minimum water losses. Quality of agriculture product could be improved by adopting this high pressurized irrigation system, as the supply of water to crop is through piping in this system. It was observed that it was more suitable for orchard and wide spread crops (Muhammad et al., 2010).

It is essential to test, design and evaluate the drip irrigation system to achieve the maximum efficiency of irrigation with low cost. The work is being done on designing of drip irrigation in many countries especially for orchards and also for other crops. In designing of drip irrigation system number of emitters per plant and spacing of laterals are very important parameters for efficient use of water. So, a well-designed drip irrigation system practically leaves no water for runoff, evaporation and deep percolation.

PVC pipes commonly used for main and sub main pipe line, while polyethylene pipe (PE pipe) are used as sub main pipe line or for laterals pipe lines. High density polyethylene pipe (HDPE) and low density polyethylene pipes (LDPE) are also introduced in the market, which are low in price and widely used in laterals. During the supply of water to plant or crop, there are some friction losses as head losses occur in the piping system. Friction loss is the portion of pressure lost by fluids when moving through a pipe. Pressure losses as head losses occur at interconnecting part of pipeline as joints, fittings. To overcome this problem it is need to redesign already existing drip irrigation system so, that the efficiency of the system could be improved.

## MATERIALS AND METHODS

### Study site

The system was designed and selected for Guava orchard, located at Taqi Abbad, a village near Chiniot, Punjab. The scheme area for which the drip irrigation system designed was 4.60 ha. The topography of the land was flat.

### Data collection and analysis

The soil of the stud area was sandy loam. Soil properties and analysis showed that the EC was 1.09dS/m, organic matter was 0.60, pH was 8.10, available P was 2.18mg/l and available K was 39.17mg/l. The water analysis showed that water was of good quality and fit for irrigation.

### Redesigning of drip irrigation system

Drip irrigation system can be divided into two sub-units, i.e. power unit and field unit. The design of the drip irrigation system was decided according to the area to be irrigated, crops of the area to be grown, type of soil and climate of the area. Zoning of the area was the first step for designing. The area under study was divided into 6 zones 1-4 and 5-6 rather into 8 zones because of the topography of the area was flat and also reduced the cost. The following relationships were used for designing of the system.

Peak daily crop water requirement was calculated by using the following relationship.

$CWR = (ETo \times Kc \times K)/\text{Irrigation efficiency}$

Where

K = Canopy factor

Kc = Crop Coefficient

ETo = Crop Evapotranspiration (mm/hr)

No. of Plants, $Np = (\text{Total area})/ (P\times P) (R\times R)$

$P\times P$ = Plant to plant distance, $R\times R$ = Row to Row distance

Total No. of drippers installed on plants were calculated as

$D_d$ = Total plants × Emitters per plant

Where

$D_d$ = No. of drippers

$T_F = D_d \times$ flow rate of emitter

$T_F$=Total flow

$D_{LL}$ = Total Area/ R×R

$D_{LL}$=Drip line length

Where application rate (mm/hr), operation time ($O_T$) and No. of plant on lateral calculated by using the relationship as given below;

$A_R$ = Total flow of a zone/ Area of zone

Operation time (hr), $O_T = CWR/A_R$

$N_{PL}$ = Lateral length/ P×P

Flow of laterals found as

$F_L$ = Total emitters on laterals x flow rate of emitter

Head loss was calculated by the relationship given by Water and Keller

$H_L\ (m) = KQ^{1.75}/D^{4.75}$

Where

Q = Flow rate of lateral ($m^3$)

K= constant

D = Internal dia. of lateral (mm)

Horse power required can be calculated by using equation as given below.

$HP = (Q \times H) / (75\times ME\times PE)$

The efficiencies for pump and diesel engine were assumed to be 60 and 70%, respectively.

Whereas, ME = Motor efficiency and PE = Pump efficiency.

### Pipe losses

Due to difference in inside cross sectional area, wet surface and roughness of the surface, there was significant difference in friction head loss. Most of the work was developed based on experimental data. Williams and Hazen (1933) formula was concerned to calculate the head losses as given below:

$h_f = 1.212\times10^{12} \times ( Q/C)^{1.852} \times D^{-4.87}$

Where,

$h_f$=head loss (m)

C = friction coefficient

D = inside diameter of the pipe (mm)

## RESULTS AND DISCUSSION

### Plant and emitters spacing

When plant spacing was reduced from 4.88 to 4.57m in zones 5 and 6for new plants, the canopy area was increased from 12.20 to 12.53$m^2$because of less roots development. The total numbers of emitters (8 lph) for one mature plant were 4 and for the new plant, were 6. In this way, the number of emitters increased from 5749 to 9860.

### Irrigation requirement

When the zones were reduced, the total flow rate was reduced from 164394 to 132256 lph and operation time was decreased from 1.74 hrs to 0.97 hrs for each zone in first four zones and from 4.38 to 2.48 hrs for each zone in zone-5 and zone-6, respectively. This was due to the decrease in the number of zones, which resulted in the decrease of operation time. Irrigation system efficiency in drip irrigation system was observed as 90% (Bhutta and Azhar, 2005). Peak daily consumptive use per day was increased from 4.55 to 5.72 mm/day.

**Head losses**

Head loss decreased in lateral design from 1.76 to 1.38m and the maximum flow rate of laterals decreased from 1026 to 440 lph for first four zones and decreased from 1026 to 384 lph in last two zones. The flow of sub main in first four zones, decreased from 23598 to 22240 lph and total head loss increased from 0.81 to 1.16m in sub main of 82.3 internal diameters. In main line, total head loss was decreased from 9.51 to 4.45m, which was less than losses in already installed system. Therefore, the new design is better than the existing system for the improvement of losses (Aiello et al., 2013).

**Pump requirement**

In the proposed design, the required horse power (estimated) was 6.16 hp with pump and motor efficiency of 65and 70%, respectively. Pump horse power was reduced due to the division of flow. Total dynamic head calculated in proposed design was 34.05m, which was less than 40.17m in already installed system. This was due to reduction in zones and showed the perfection of design.

**Comparison of cost**

The installation cost was reduced from 1.28 to 1.136 million rupees. The comparison of cost showed that the proposed design was economical and efficient.

**Losses in pipes**

Three different types of pipes i.e. polyvinyl chloride (PVC), poly-ethylene (PE) and galvanized iron (GI) pipes were studied and head losses at different discharges were calculated in these pipes. Detail description of losses at different diameters of pipes is given below:

**Losses in 82.3mm pipe**

For 9000 lph discharge through the pipes of 82.3mm diameter (internal), the values of head losses were calculated as 0.29, 0.33 and 0.44m for PVC, PE and GI Pipes, respectively. The minimum head loss was found within the PVC pipe than the other pipe and less than 1.5m head loss has been recommended for best design (Thakur and Spehia, 2005). The graphical presentation of types of pipe and head losses at 9000 lph is given in Fig 1.

The increase in head loss value was due to friction by the pipe. These values showed that the pipe within diameter 82.3mm was suitable for discharge at 9000 lph.

**Losses in 54.5mm pipe**

For pipe of diameter 54.5mm the head losses occurred within PVC, PE and GI Pipe were 2.15, 2.45 and 3.26m, respectively at a discharge of 9000 lph. These head losses were more than 1.5m, which showed that more friction faced by fluid during passing through pipe of 54.4mm diameter and pipe was also under stress. Thus, the diameter 54.5mm was not suitable for discharge 9000 lph. The price would be decreased but losses were more and water distribution was not uniform.

The experiment repeated for the discharge of 6000 lph. The head losses were found as 1.02m for PVC pipe, 1.15 m for PE pipe and 1.5 m for GI pipe, showed the

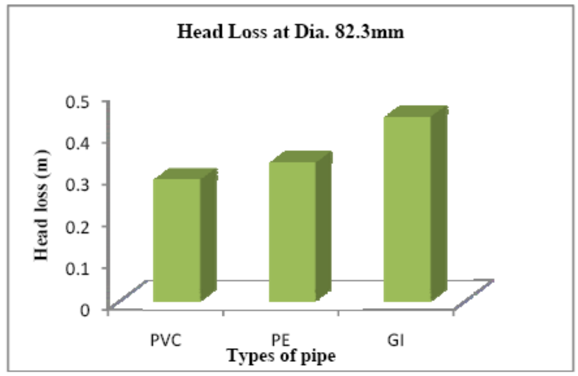


**Fig. 1: Types of pipe and head losses**

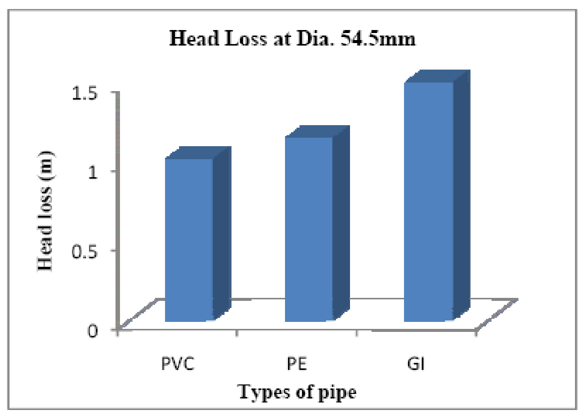


**Fig. 2: Types of pipe and head losses**

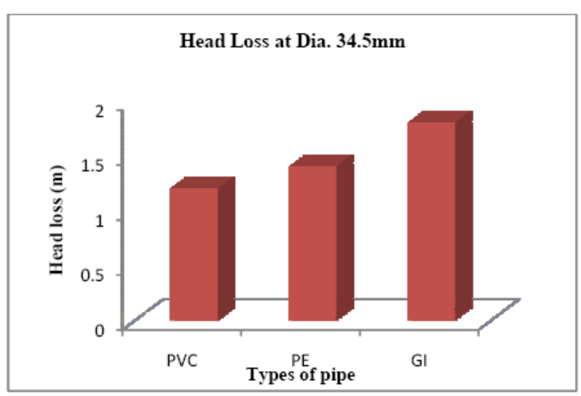


**Fig. 3: Types of pipe and head losses**

**Table 1: Comparison of pipe losses**

| Types of pipe | Diameter (internal) (mm) | Head losses at 9000lph (m) | Head losses at 6000lph (m) |
|---|---|---|---|
| PVC Pipe | 54.5 | 2.15 | 1.02 |
| PE Pipe | 54.5 | 2.45 | 1.15 |
| GI Pipe | 54.5 | 3.26 | 1.5 |

**Table 2: Comparison of pipe losses**

| Types of pipe | Diameter (internal) (mm) | Head losses at 9000lph (m) | Head losses at 6000lph (m) | Head losses at 2000lph (m) |
|---|---|---|---|---|
| PVC Pipe | 34.5 | 20 | 9.4 | 1.2 |
| PE Pipe | 34.5 | 22.7 | 10.7 | 1.4 |
| GI Pipe | 34.5 | 26.1 | 12.3 | 1.8 |

compatibility of pipe diameter with the discharge. The information of comparative losses is given in Table 1.

The variation in values was found by the effect of friction in pipes. The graphical presentation of types of pipe and head losses at 6000 lph is given in Fig 2.

In GI pipe, the head loss was more due to more friction and roughness of the surface, that's why it was not used as sub-main line or laterals, which could increase the price of the system (Hea et al., 2013).

**Losses at 34.5mm diameter**

When the discharge of 9000 lph passed through the PVC pipe of diameter 34.5m, the head losses were found 20m which was more than 1.5m and hence not in acceptable limit. The suitable discharge for diameter 34.5 m was 2000 lph. The losses calculated were 1.2, 1.4 and 1.8m for PVC, PE and GI pipes, respectively. The information of comparative losses is given in Table 2.

The losses within PVC pipe and PE pipe were less than 1.5 m showed compatibility between pipe diameter and discharge. The variation in pipe losses with diameter is shown in Fig 3.

More losses occurred when discharge was more and pipe diameter was less or vice versa. Within the GI pipe, the losses occurring more because 1.8 m head loss more than 1.5m head loss but it felt less stress than the other pipe. So, it could be used for 2000 lph discharge. The head losses for PE pipe has marginal values and used as main line, sub-main line and could also be used for laterals.

**Conclusions**

It was concluded that plant to plant and row to row distance was very important in designing of drip irrigation system. Emitters per plant used for small plant but for mature plant emitters were used because they required more water for their growth. While in sandy soil bubblers were not used because all water was absorbed by soil even unused by plant, Head losses were not increased than 1.5m and flow did not exceed more than 2000 lph as compared to other zones and ensure energy saving and uniform flow of water. Pipe size was used according the flow rate to minimize the losses.

**Acknowledgements**

The facilities provided by the On Farm Water Management, Punjab Agriculture Department, Lahore, for conducting this study at their fields are acknowledged.

## REFERENCES

Aiello R, GL Cirelli, S Consolli, F Licciardello and A Toscando, 2013. Risk assessment of treated municipal wastewater reuse in Sicily. Water Science Technology, 67: 89-98.

Bhutta MN and AH Azhar, 2005. A proposal for Sprinkler Irrigation Model Farm at Mirani Dam Project (MDP), Turbat. IWARSI Internal Report No. 2005/01.

Hea J, M Dougherty, FJ Arriaga and AH Abdel Gadir, 2013. Impact of a real-time controlled wastewater subsurface drip disposal system on the selected chemical properties of a vertisol. Environmental Technology, 34: 1341-7.

Muhammad D, I Raza, S Ahmad, MN Afzal and MA Mian, 2010. Efficiency of Drip VS Furrow Irrigation System with variable plant density on Cotton under Southern Punjab Climatic Condition. Central Cotton Research Institute, Multan, Pakistan.

PAS, 2006. Agriculture Statistics of Pakistan. Ministry of Food, Agriculture & Livestock. Government of Pakistan.

Qureshi AS, 2011. Water Management in the Indus Basin in Pakistan: Challenges and Opportunities. Mountain Research and Development, 31: 252-260.

Thakur BC and RS Spehia, 2005. Effect of drip lateral spacing and crop geometry on yield and quality of tomato under drip irrigation. Research on Crops, 6: 246-249.

Williams GS and A Hazen, 1933. Hydraulic Tables, 3rd Edition, John Wiley & Sons, Inc., New York, USA.