International Journal of Information Science and Computing 2(1): June, 2015: pp. 13-20

Capillary Water Provision System for Irrigation

Joju Thomas K, Kiran Thomas, Christin Thomas, Dheeraj M and Philip Jacob Perakathu

Department of Mechanical Engineering, Saintgits College of Engineering, Kottukulam Hills, Pathamuttom P.O, Kottayam-686532, Kerala, India.

Corresponding author: jokochettu@gmail.com

Abstract

Water provision system using capillary action is a restoration propagation operation. The capillary action occurs due to the combined effect of three phenomena's namely cohesion, adhesion, and surface tension. This is a low cost approach to supply an efficient and continuous source of moisture to plants. A variety of materials can be used to construct this system. In this study, a system has been designed and water is allowed to reach the root of plants through capillary action. For the betterment of water transfer, a porous material is embedded into the system. Using this system water can be provided to a certain height without the aid of mechanical devices like motor and pump. This method can be used to provide water to small plants and also to large plants in their initial growing stages. This largely helps in reducing wastage of water and helps in efficient use of water especially in water scarce regions. This system can be modified for more applications in the future.

Keywords: Capillarity, surface tension

Introduction

For the improved use of water in agriculture several techniques have been implemented. One such technique is the method of using capillary irrigation systems. Capillary action or wicking is the ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity. The effect can be seen in the drawing up of liquids between the hairs of a paint-brush, in a thin tube, in porous materials such as paper, in some non-porous materials such as liquefied carbon fiber, or in a cell. It occurs because of inter-molecular force between the liquid and surrounding solid surfaces. If the diameter of the tube is sufficiently small, then the combination of surface tension which is caused by cohesion within the liquid and adhesive forces between the liquid and container act to lift the liquid. In short, the capillary action is due to the pressure of cohesion and adhesion which cause the liquid to work against gravity. The water provision system using the capillary action is a restoration propagation operation. It gives a constant and steady supply of moisture to the root zones of plants from the bottom up. In this study we use porous materials like tissues for the betterment of capillary action the porous material is stacked within the pipe and the porous medium is provided till the roots. It was found that water is rising through the porous material due to the effect of root pressure. The design and analysis have been done and the prototype has been made and found that water is reaching the root outlets, the height of rise depends on root pressure of selected plants. From various data's collected it has been observed that for different plants the root pressure varies from about 33 Pa to about 0.6 MPa. So for this study we are taking two root pressures. First we take a root pressure of 33 Pa which is least and can study the effect of smallest pressure plants in our designed system. Secondly we take an intermediate root pressure range 2.5 kPa, which is the root pressure of grape vines. Study and analysis are done for both cases and different heights up to which water can rise has been determined.

Materials and Methods

In this method glass tubes having different diameters were taken and dipped in a container having water. So that the water level rises in each tube vary according to its diameter which can be clearly seen.

Capillary tubes of varying diameters

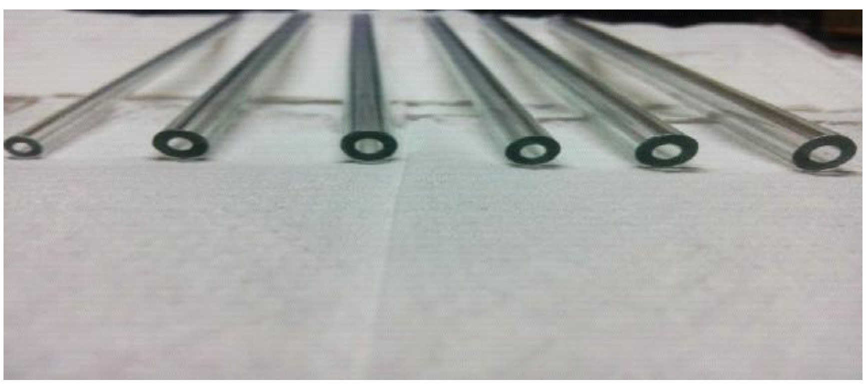

Fig. 1. Capillary Tubes of Varying Diameter

The glass tubes used in the study are having diameters of different values. Figure 5.1 shows glass tubes of different diameters. This includes capillary tubes with diameter 2 mm, 2.5 mm, 3 mm, 3.5 mm, 4 mm, and 5 mm respectively. When these tubes are dipped with its one end within a container having water, it is observed that the level of water rise in each tube is different. This is because of the varying diameter of the tube.

It can be clearly inferred from the figure 2 that the tube with the least diameter is supporting the highest water rise, when compared with the other tubes. And the tube with the largest diameter is giving the least rise.

Major problems resulting in this method is that: the water rise though it is been obtaining, but the rise is in the millimetre range only. This will not helps in producing an efficient water provision system.

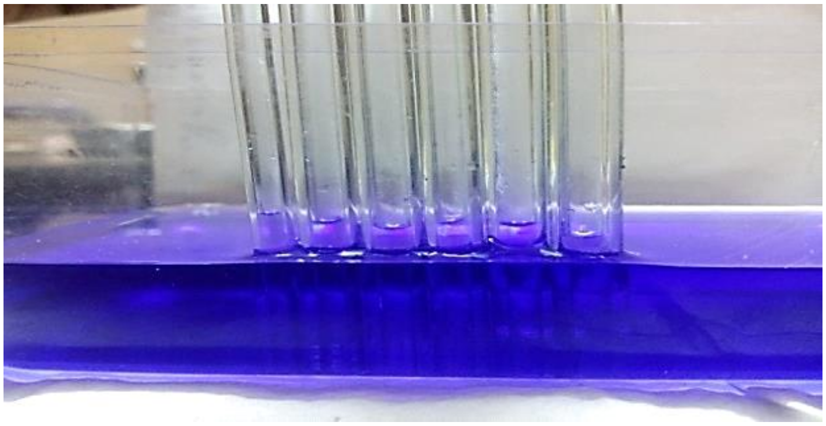

Fig. 2. Varying level of water in capillary

Porous material within the capillary tube

To overcome the problem faced in the first method i.e., the low water rise in the tube, a porous material is been used by stacking within the tube. Due to easy availability and to make economic, paper towel is been used in this case. Sponge can also be used. The water rise through a porous material will be much higher as compared to the rise in a capillary tube. This is due to the better adhesiveness between the two mediums. So, when this porous material is used within the glass tube then the resultant rise of water within the tube will be much higher as compared to that in the first case. This helps in attaining the study objective of providing water to more height which can be used for irrigation purposes.

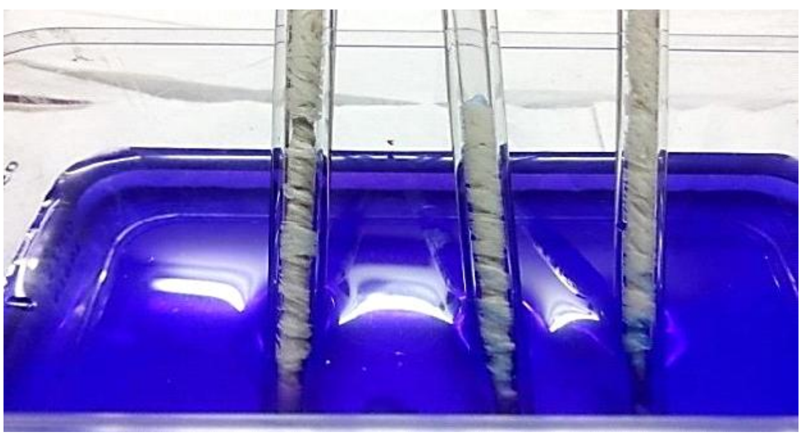

Fig. 3. Porous material stacked within capillary tube

Porous material within PVC pipe

In order to overcome the problems faced in the above methods, a system of a pipe made some other material within which porous material is been kept to achieve the desired functional system. Pipe made of any recycled materials or other low cost material can be used. In this method a PVC pipe was used. But with its use the rise of water through it cannot be obtained as that in the case of capillary tubes. For achieving that, the porous material has been kept within the tube. This helps water to rise through the tube.

In this, water is been filled in the larger pipe which is the main line. While the porous material was kept within the branch pipe which of smaller diameter so that water will be raised from the main line to the top section of the branch pipe through capillary action. Small holes have been provided at the top of the branch pipe so that the water can be provided to outside and when a plant root comes in contact with the porous material, it will takes in the required amount of water from the wet paper towel.

Fig. 4. Prototype of the proposed system

Thus, through the system the main objective of developing an efficient water provision system using capillary action was obtained. This largely helps in reducing the water usage in plants, reduces labour, reduce total cost involved.

Design and Analysis

Design using solidworks

Figure 5 shows the designed water provision system for 5 cm height. The water inlet and outlet are given as the opening and ending portion of bottom main pipe. The branch pipes which are place at different heights are stacked with porous medium, and the outlets which were given on the branch pipes are the outlet to the roots.

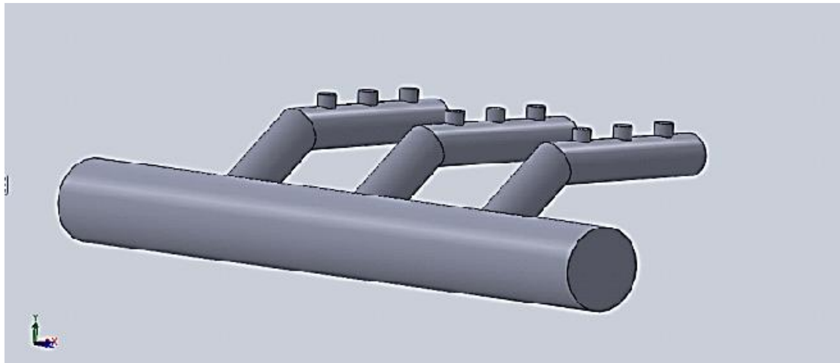

Fig. 5. Designed model

Analysis using ANSYS

Velocity and pressure analysis were carried out using ANSYS FLUENT. This analysis is mainly done in order to find out up to what height water can rise through the porous material due to capillary action for the root pressure considered.

Analysis for root pressure (-33 pa) for various heights

The analysis for different heights has been done and the results for different heights have been shown below. The boundary conditions given are inlet and outlet of main pipe as 1 atm, root outlet pressure as –33 Pa and porosity of medium as 0.8. From the analysis it was found out that water can rise up to a height of 7.5 cm for a root pressure of -33 Pa.

The velocity and pressure contour for different heights of 2.5 cm, 5 cm and 7.5 cm is shown in the Figures 6, 7 and 8 respectively.

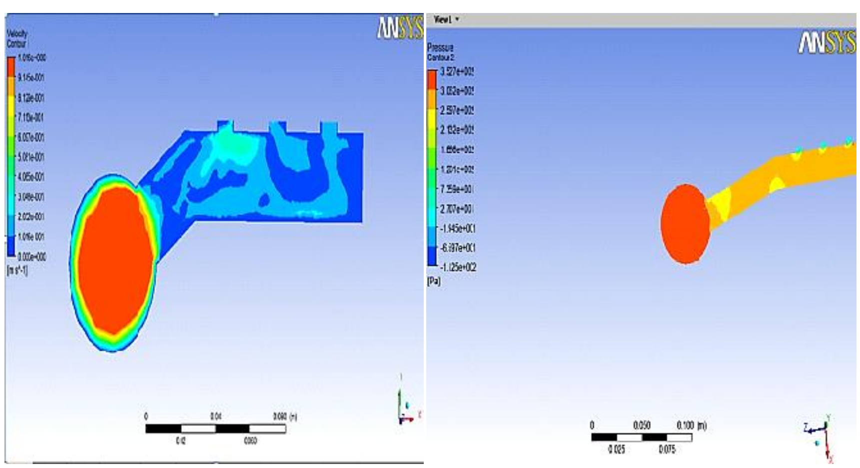

Fig. 6. Velocity and Pressure contour for height 2.5cm

Figure 6 show that water is reaching all the root outlets uniformly with a uniform velocity. The pressure contour shows that the upward pressure acting on the system decreases from bottom to top. There for it can be inferred that there is upward force acting throughout the pipes from bottom to the root outlets.

From the velocity and pressure contour for 5 cm height shown in Figure 7 it can be inferred that water is not reaching all the root outlets in a uniform manner. As the distance of the root outlet from the main pipe increases the ease with which water reaching the outlet reduces.

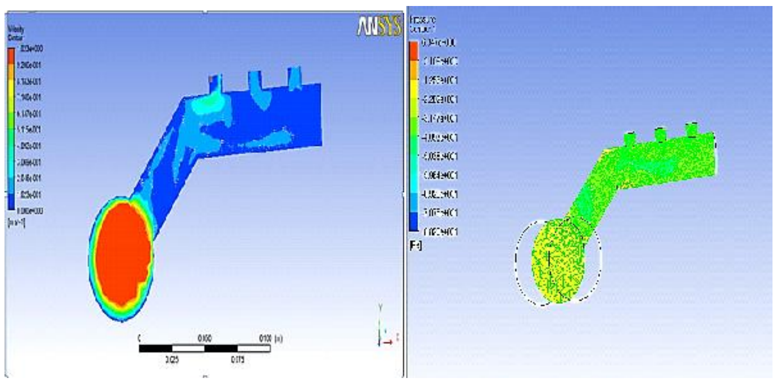

Fig. 7. Velocity and Pressure contour for height 5 cm

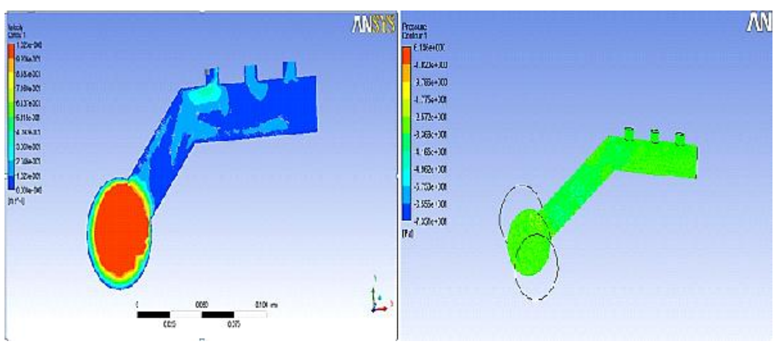

Fig. 8. Velocity and Pressure contour for height 7.5 cm

From the velocity and pressure contour for 7.5 cm height shown in the Figure 8 above it can be clearly inferred that water is reaching the farthest root outlet with a much lower velocity when compared with the root outlet at the beginning. From the pressure contour it is clear that the upward pressure is not as high as the above two cases. The maximum height water can be provided using root pressure -33 Pa is 7.5 cm. For plants with root pressure more than -33 Pa water will easily move up and will be capable of obtaining water from more depth.

Analysis for root pressure (-2.5 kpa) with various heights

The analysis for different heights has done and the results were shown below. The boundary conditions given are inlet and outlet of main pipe as 1 atm, root outlet pressure as –2.5 kPa and porosity of medium as 0.8. From the analysis the maximum possible height is 2 m.

Velocity and pressure contours for heights 1.5 m and 2 m are shown in the Figures 9 and 10 respectively. For both the heights the velocity with which water reaching each root outlet was uniform. The pressure reduces from bottom to the root outlets, therefore an upward pressure is acting from bottom up.

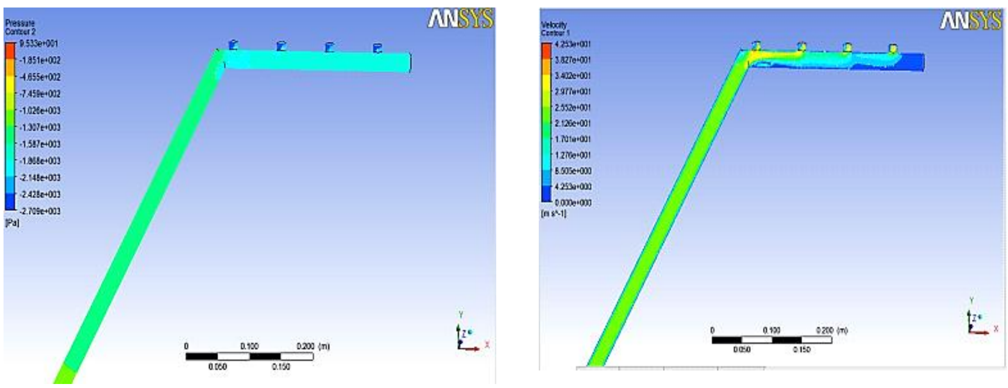

Fig. 9. Velocity and pressure contour for height 1.5 m

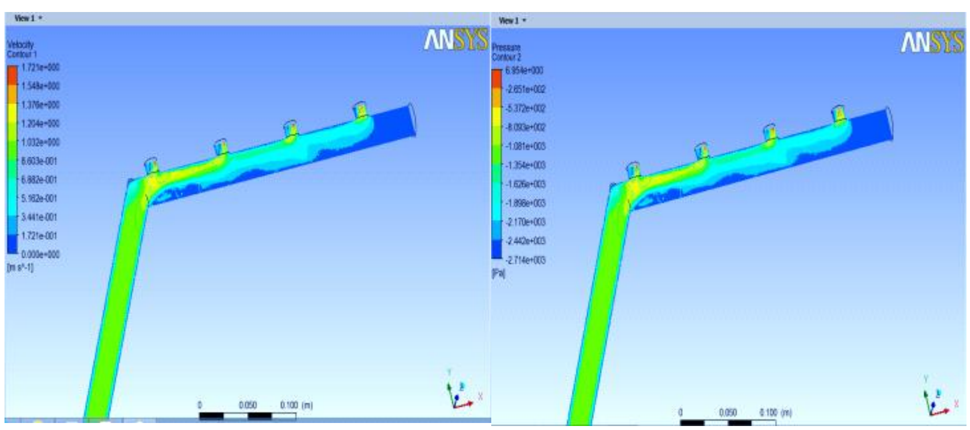

Fig. 10. Velocity and pressure contour for height 2 m

Results and Discussion

The study, design and analysis of water provision system using capillary action have been carried out in this study. From the analysis carried out using ANSYS, it can be concluded that the height to which water can rise through the tube depends on the root pressure of the plant under consideration. Therefore this system can be effectively used for providing water needed for their growth. For plants with root pressure higher than the designed system, water intake will be possible. In the case of small plants, the root pressure was found to be higher. This enables the use of the proposed system in nurseries.

The system has several advantages over conventional drip irrigation system which are: the cost involved is much less compared to the other. Fabrication is simpler and the maintenance involved is very less. Since PVC pipes are used in the current project it has life time of about 10-15 years. The porous material used has to be renewed once in 3 or 4 months. The system design is very simple compared to the conventional drip irrigation system.

With this system water required for the plants is supplied effectively. This helps in reducing the water requirement and also helps in avoiding the use of motors and pumps as in conventional irrigation systems. Thus the system developed helps in attaining more profit.

In addition to the advantages proposed above, the system can be used for research purposes for determining the exact usage of water by the plants. By the use of hybrid porous materials the efficiency of the system may be further improved. The system may be adopted in water scarce areas thereby helping in achieving continuous irrigation purposes.

References

1. Sperry *et al.*, "Spring Filling of Xylem Vessels in Wild Grapevine," *Plant Physiol*, Vol. 83, 1987, pp .414-417.

2. Beuther *et al.*, "Characterization of Absorbent Flow Rate in Towel and Tissue," *Journal of Engineered Fibers and Fabrics*, Vol.5, Issue 2, 2010, pp. 1-7.

3. Githinji *et al.*, "Physical and hydraulic properties of inorganic amendments and.modeling their effects on water movement in sand-based root zones," *Irrig Sci*, Vol. 29, 2010, pp. 65-77.

4. Zhong Feng et al., "Experimental Study on effects of magnetization on surface.tension of water", *Procedia Engineering*, Vol. 26, 2011, pp. 501–505.

5. Ityel *et al.*, "An artificial capillary barrier to improve root-zone conditions for .horticultural crops: response of pepper, lettuce, melon, and tomato," *Irrig Sci*, ..Vol. 30, 2012, pp. 293–301.