ENGINEERING A HYDROPONIC SYSTEM FOR GROWING MANGO TREES

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Abstract

A hydroponic system was designed to maintain uniform root environment for mango flowering manipulation. Round barrels 56 cm in diameter and 87 cm tall were used as planters. The barrels were filled with inert sand as planting medium. The sand provides temporary storage for water and nutrients. The sand also helps keep the trees in an upright position. An inverted V-shaped black plastic canopy was constructed to keep precipitation from falling on the sand. This roof structure also helps keep trees from toppling over. The sand moisture and nutrient levels are maintained by adjusting the irrigation frequency and the nutrient concentration of the irrigation water. A drain was installed on each barrel to collect excess water accumulated at the bottom. This drain was useful in collecting water samples for chemical determination and water budgeting. Eight different root environment treatments of four trees per treatment can be accommodated in the present design. Trees have been grown in these barrels for approximately three years.

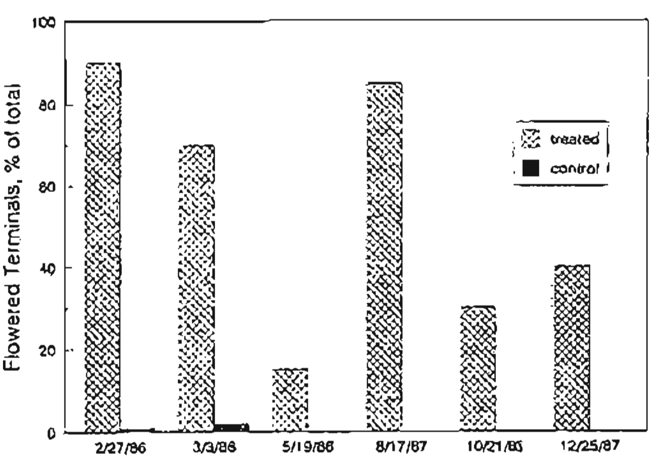

Figure 1. Potassium nitrate effect on mango flowering.

Introduction

Mango is a tropical fruit tree which usually flowers in spring and produces attractive fruits in June or July. Mangos, like many other tropic fruit trees, do not flower consistently. Inducing mango flowering was done in the past. Early experiments were aimed to induce early flowers. This experiment, however, focuses primarily on inducing flowering at any time of the year. With fruits available all year, the amount of mango which could be sold to the 6.5 million tourists to Hawaii can be very significant. Potassium nitrate solution was used to spray mango terminals for flower induction with some success. The spray concentration of 40 g potassium nitrate in 1 l of water was found to be the most effective. Terminals were induced to flower in all seasons (Figure 1). The success rate was, however, much lower in the summer months and a great deal higher in spring, or normal mango flowering season. Even during spring, terminals of approximately the same age do not all flower. Obviously, factors other than potassium nitrate played an important role in the mango flower induction experiment. Publications have identified soil moisture, soil fertility, temperature and terminal age as significant factors in mango flowering. Ability to keep root environment of all treatments under the same conditions can simplify the design and interpretation of results of flower induction experiments. Hydroponics was therefore selected to achieve uniform root environment.

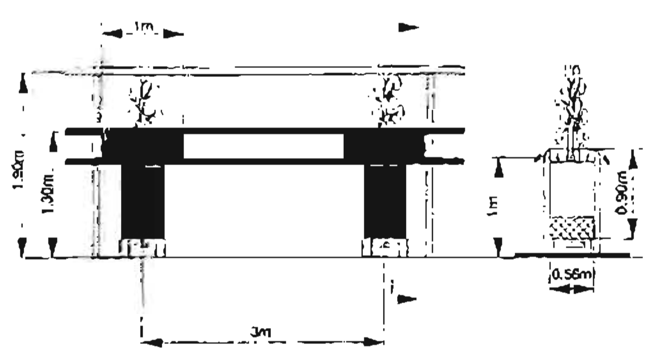

Figure 2. The planter.

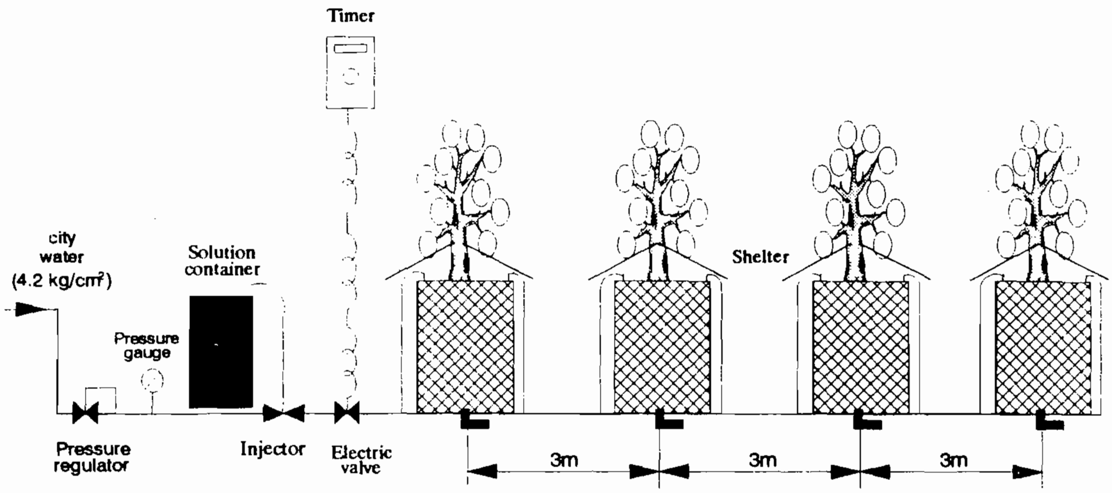

Figure 3. Irrigation components.

The Hydroponic System

The system must be able to provide mechanical support to hold the trees upright and deliver water and nutriment to each tree at minimal energy and cost. It is extremely important to keep the daily system maintenance low. The major components of the system are shown in Figure 2. A tubular frame was anchored to the ground and a V-shaped angle iron truss was attached to the tubular frame. Under the V-shaped truss, planters were arranged 3 m apart along the frame. Metal drums with plastic liners of 56 cm in diameter and 1 m high were used as planters, placed on cinder or hollow concrete tiles. Inert sand was placed on top of a layer of gravel on the bottom of the planters. A drain was also installed at the bottom of each planter. On top of the truss, a black plastic sheet was installed to keep the sand surface in the dark and prevent any weeds from growing in the planter. The mango canopy, however, is kept above the plastic sheet on the V-shaped truss and exposed to sunlight. The floor was covered with a black plastic weed-control cloth to keep the ground free of weeds.

Planters are arranged 3 m apart along the tubular frame (Figure 3). Tap water was used for irrigation. Major components used for irrigation and fertilizing, as shown in Figure 3, include city water pressure regulator, pressure gauge, fertilizer injector and a container holding fertilizer solution. The water pressure and the concentration of fertilizer in the solution determines the nutrient concentration of the solution. The timer and solenoid valve determine how long or how much the trees will be irrigated. Experiments were conducted to verify whether the irrigation system performed satisfactorily. To make the drawing in Figure 3 easy to understand, a tubular frame was not shown. Furthermore, the V-shaped truss was also turned 90 degrees. The system is an open one; in other words, irrigation water was not recirculated. The drain valve in each planter was always kept open and the excess water, if any, was drained automatically. This open system was selected to minimize fabrication effort and reduce the spreading of disease. The entire experimental hydroponic system consists of four 25-m long tubular frames providing supports and shading for a total of 32 trees.

The quantity of parts and materials and their cost per barrel or tree are listed in Table 1. The most expensive items for each tree are the planter barrel and inert sand. For this experiment, soybean-paste containers were obtained at nominal cost as planters. They have stood well and no rust can be found after three years in use. Any food containers made of lasting materials can be reused for this purpose at very low or even no cost. Silica sand #12 was not easy to purchase in Hawaii and, therefore, a high price was paid for the sand. This amount of sand or similar material with the same texture can be purchased at a small fraction of the cost elsewhere. The material and parts cost of establishing a tree for most locations probably can be controlled under US$70.00.

In addition, there was a component cost common to a line of trees under the same irrigation treatment (Table 2). The first four items can be shared by all trees if they are under the same treatment. When all trees are treated or

Table 1. Planter parts and their cost.

Description	Quantity	Cost, US$
Grafted mango tree	1	20.00
Barrel (55 gal)	1	5.00
2B coarse rock	62.3 l	1.40
#12 silica sand	158.6 l	53.00
Concrete tile or block (16 x 16 x 8 in)	3	4.00
Emitters	2	2.00
Emitter tubing (1/8 in)	2	2.00
Fittings incl. tank adapter, elbow, and pipe drain	1	5.00
Weed control cloth	4.5 sq m	4.00
Plastic covers (30 x 54 in)	2	8.00
Angle iron (1 x 1 x 3/16 in)	4.57 m	8.00
1-1/2 in EMT conduit	2.13 m	11.00
Poly pipe	3.05 m	1.60
Total		125.00

Table 2. Common irrigation components.

Description	Quantity	Cost, US$
Pressure regulator (3/4 in)	1	40.00
Filter (3/4 in)	1	30.00
Backflow preventer	1	20.00
Solenoid valve	1	40.00
Timer (mechanical)	1	40.00
Barrel for fertilizer	1	5.00
Fertilizer-metering injector	1	40.00
Electrical		15.00
Poly pipe		15.00
Pipe fittings		20.00
Total		$265.00

irrigated in the same manner, the items listed in Table 2 should serve a large number of trees, except that a multiple-channel timer must be purchased.

System Performance

An experiment was conducted to determine the evapotranspiration, or the water requirement of each tree. It was felt that the most accurate way of accomplishing this objective was to water the planters in different amounts and collect water

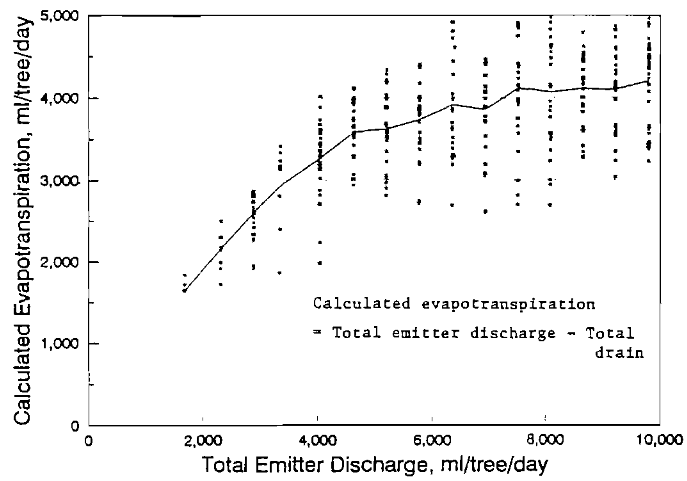

Figure 4. Evapotranspiration.

drained from each planter. Solar radiation was used to estimate the potential evapotranspiration, which was used as a reference for determining the range of water amounts to be used in the experiment. Approximately 15 levels, or amounts, of water were used. At low levels of water application, there was little drained water. The difference between water applied to each planter and the drain water collected was assumed to be equal to the evapotranspiration of the planter. The results of this experiment were plotted in Figure 4. The evapotranspiration of each tree seems to be 4 l/day. As trees grow bigger, it is expected that the water requirement should increase. The small spacing between trees and the fixed planter size would probably limit the tree to a certain size and, hence, limit the maximum water requirement.

Besides delivering the desired amount of water to each tree daily, it is also important to maintain the correct fertilizer amount or nutrient level in the irrigation water. Technology used in fertigation was used to achieve this objective. The principle is based on a venturi injector connected to a pressured water source and to fertilizer dissolved in water in a container. The chemical content of the fertilizer used is displayed in Table 3. The fertilizer solution is connected to the injector port under a suction created by the flow of water under pressure. A test was conducted first to determine if the flow of liquid fertilizer can be adjusted by selecting the injector type and water pressure. Eight tests were run and the results are plotted in Figure 5. The dark bar represents the desired flow and other bars show the actual flow measured. Even in the worst case, the discrepancy

Table 3. Fertilizer chemical content.

Element	Weight (%)
N	9.25
P_2O_5	7.5
K_2O	13.0
Ca	9.5
Mg	1.8
S	2.25
B	0.095
Cu	0.025
Fe	0.2
Mn	0.105
Zn	0.025
Inert material	56.25

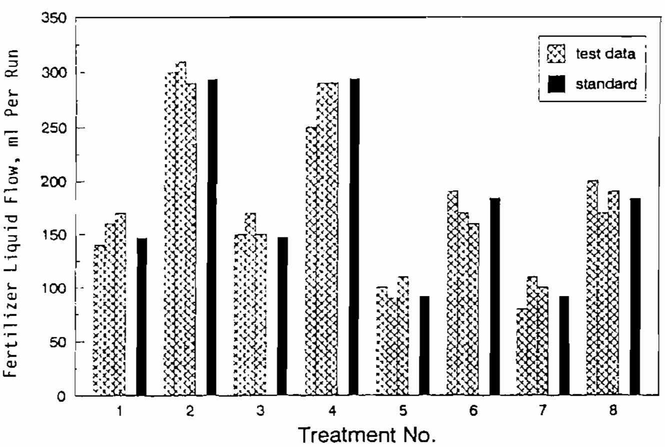

Figure 5. Calibrating fertilizer solution flow.

is less than 5 percent. Similar tests were conducted to determine the total emitter discharge. The results are displayed in Figure 6. The error or discrepancy was negligible. It may be safely stated that the desired irrigation amount and nutrient level in the irrigation water can be achieved.

Trees were first irrigated and fertilized at eight different levels to determine the best level of irrigation and fertilization. The circumference of the trees was used as the measure of irrigation and fertilization effectiveness. Unfortunately, this experiment was conducted before the evapotranspiration was determined. All trees were under-irrigated. Therefore, no difference were found between the treatments. However, the trees did grow more than 20 percent in three months (Figure 7) during this short period of time.

Conclusion

Mango trees have been grown hydroponically for over three years. Tree trunks have grown from pencil size to more than 4 cm diameter. The amount of irrigation was determined by minimizing the amount of water flowing out of the drain. However, attempts to determine the optimal fertilizer level were not successful. An acceptable way to prune or shape the trees remains to be determined. Flowering induction experiments must wait until these two problems are solved.

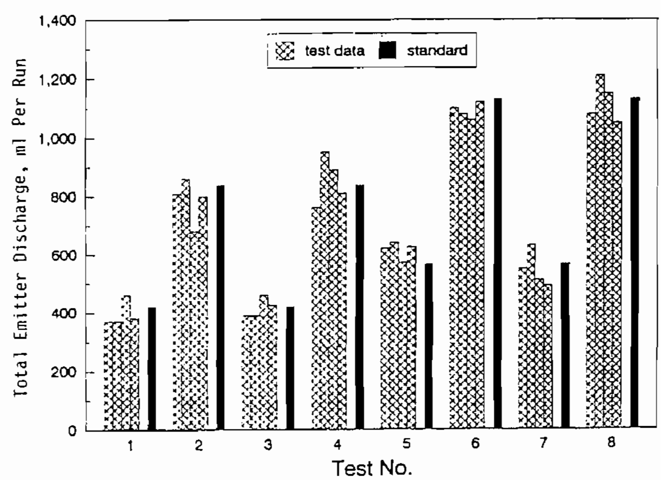

Figure 6. Calibrating total flow.

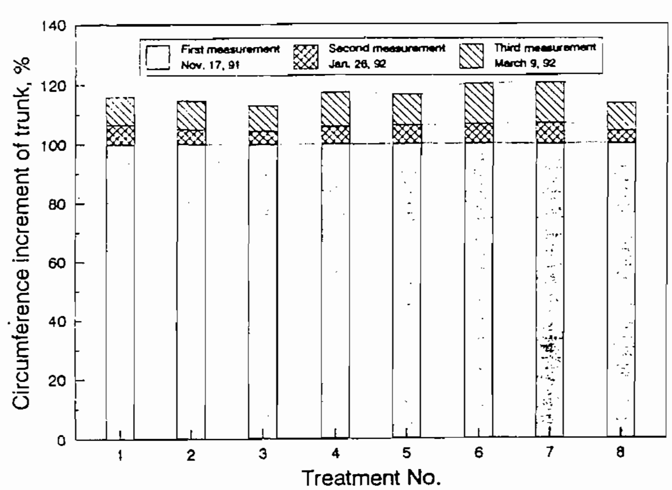

Figure 7. Tree trunk growth.