Building a Appropriate Irrigation System for Tropical Fruit Productions in Taiwan – in the case of papaya

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Executive Summary

Climate change in recent years is having a severe impact on the cultivation of tropical fruits in Taiwan. In an effort to stabilize yield, improve quality, save costs on labor and fertilizer, our research projects on water conservation through more efficient and precise irrigation have received much attention for the tropical fruit production region suffering from limited water supply. Papaya required large amounts of water and fertilizer during growing period; therefore it served as a good model plant for the development of appropriate irrigation system for tropical fruit trees. We designed a series of experiments related to the fertigation for papaya included appropriate fertilizer utilization, using tensionmeter to monitor irrigation requirement and comparing traditional micro spray tape irrigation and fertigation. To teach and promote techniques in fertigation for fruit trees, we had established a demonstration field for papaya fertigation management using existing equipment and design a proper fertigation system that is affordable. Using drip irrigation will conserve water effectively, increase fertilizer efficiency, save on labor costs and enhance yields. Fertigation is an appropriate choice of method in the management of irrigation and fertilization for the commercial production of papaya in Taiwan. Joint efforts by research institutes, irrigation associations and the farmers to promote efficient use of irrigation water and stable crop yields will be encouraged.

Introduction

Kao-Ping Area (Kaohsiung City and Pingtung County) is the major tropical fruit production area in Taiwan. Our research on tropical fruit crops focuses on improving breeding and cultural practices for papaya, wax apple, Indian jujube, litchi, mango, pitaya and guava. Climate change in recent years is having a severe impact on the

cultivation of tropical fruits in Taiwan. Drought, heavy rainfall and typhoons devastate main crop production areas more frequently around the world, including Taiwan. In Taiwan, water resources for horticultural production are becoming increasingly scarce while facing competition from alternative water demand by commercial industries and cities. Therefore, in an effort to stabilize yield, improve quality, save costs on labor and fertilizer, our research projects on water conservation through more efficient and precise irrigation have received much attention in recent years, especially for the tropical fruit production region suffering from limited water supply.

Papaya is widely cultivated in tropical and subtropical zones. In Taiwan, papaya has been planted in net-house to keep out the aphid vectors and avoid the papaya ringspot virus disease for the past 27 years. Papaya cultivated in net-house with high plant density (1800-2400 plants / ha) can produce fruits year round and yield between 100 and 150 metric tons per hectare per year in Taiwan which allow for potential for high profitability. In order to maintain its productivity, papaya requires large amounts of water and fertilizer during growing period; therefore it serves as a good model plant for the development of appropriate irrigation system for tropical fruit trees with fertigation being the main irrigation method.

Building a fertigation system for papaya

Commonly used irrigation systems for papaya in Taiwan

The average planting area for papaya orchards was about 0.3 hectare. The micro spray tape and furrow irrigation were the most widely used methods of irrigation with some micro sprinkler irrigation also available. Groundwater was used in micro spray tape and the main advantages were that the equipments were readily available and inexpensive. The disadvantages include large water consumption and uneven distribution of water which would require further manual fertilization. Such fertilization was less effective and more labor intensive. Furrow irrigation also had high water consumption. Soil without proper drainage may cause root rot in plants.

Experiments and results related to the fertigation for papaya

(1) Appropriate fertilizer utilization for papaya

Large-container planting was used to test the amount of fertilizer demands for papaya in various developmental stages. The results were as follows: The mean quantity of fertilizer applied in the experimental orchard in a two-week interval was 14 kg ha^{-1} N (NH_4NO_3), 22.9 kg ha^{-1} P_2O_5 ($(NH_4)_3PO_4$) and 12.4 kg ha^{-1} K_2O (KNO_3). Plants were given different amounts based on their age with 1/3 of the total amounts used for plants one to three months old, 1/2 of the

total used for plants four to six months old and the full amount used for plants seven months and older. The results of the experiment can be applied toward commercial production in papaya orchards. Field experiments confirmed that using the above fertilizer combination for fertigation would yield about 120-180 $t \cdot ha^{-1}$ with excellent fruit quality.

(2) Using tensionmeter to monitor irrigation requirement

Water volume and frequency of drip irrigation for papaya were influenced by factors such as plant size, growing period, mulching, soil structure, dripline, etc. Use of tensionmeter provided a convenient way to measure soil water content. In general, papaya root system growed to 30-60 cm soil depth on average and some may reach a depth of 70-90 cm. Tensionmeters positioned at 30, 60, and 90 cm soil depth along with the use of flow meter will help us investigate the changes in soil water potential affected by the flow of water before and after irrigation (fig. 1). Water content in soil was higher when tensionmeter reading was near zero. A high reading of tensionmeter indicated less water in the soil. Plant demand for water can be adjusted according to its growing season, growth stages, and the depth of the root system. During the first three months after planting, irrigation should concentrate on the top layer with higher watering frequency for shorter periods for a tensionmeter reading of 20 cbar. Irrigation should be done every three to six days and water on the top 30 cm of soil. After flowering in four-six months, irrigation depth can be increased to 30-60 cm. Apply water when the tensionmeter reading was above 30 cbar, and the watering frequency should be about 7-10 days. Seven to ten months after planting when the fruits were maturing and during harvesting, water infiltration should reach 90 cm to guide papaya root system to continue to grow downwards. Water potential at the top 30cm layer of soil should be maintained at 30 cbar and can be increased to 50-60 cbar at 30-60 cm soil depth. Irrigation schedule should be about every seven to ten days. Using the drip fertigation stewardship as described, 150-180 tons per hectare per week of water should be sufficient for highly productive papaya (fig. 4).

Fig. 1 Tentionmeters installed at three different soil depths – 30, 60, 90 cm.
（from: http://www.netafim.com/）

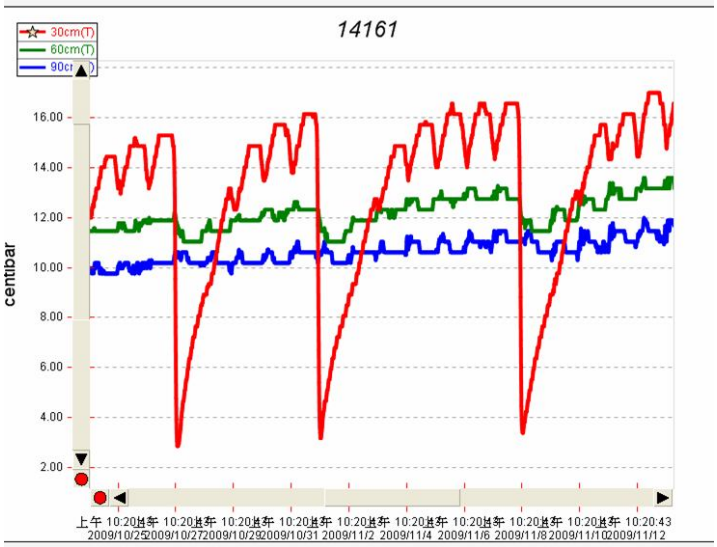

Fig. 2 Red, green, blue lines represent water content in soil at 30, 60, 90cm soil depth. After irrigation, red line drops sharply, green line declines slightly, and blue line remains almost unchanged, indicating that irrigation depth is near the 0-30 cm region.

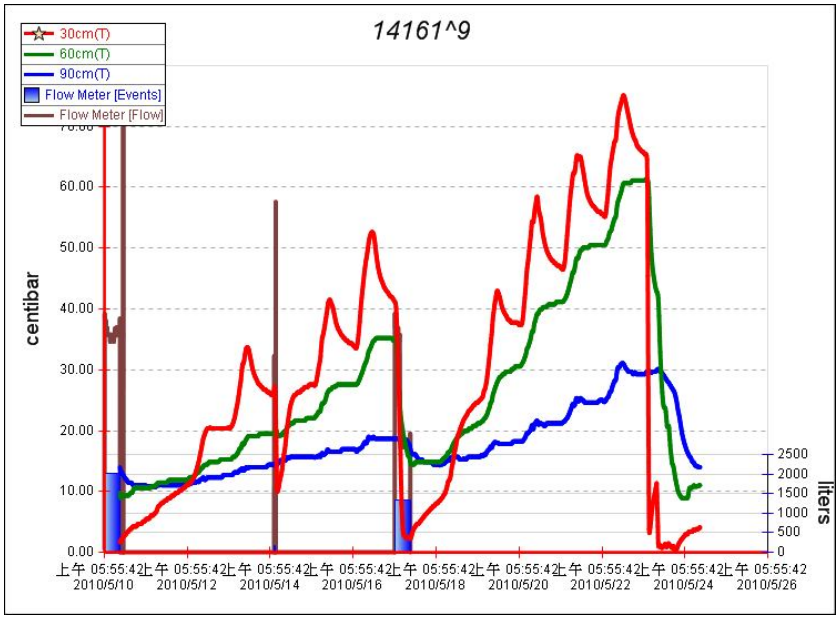

Fig. 3 Leaf area is wider and the plant is more efficient in transpiration close to harvest. At this time irrigation depth should reach 90 cm and soil water tension should temporarily reach 50-60 cbar at 30-60 cm soil depth. (Blue bars represent volume of irrigation water, brown bars represent rate of water flow)

Fig 4. Papaya experimental field in KDARES

(3) Comparing traditional micro spray tape irrigation and fertigation:

Results from above experiment along with past experience can be drawn upon to assist the less experienced fruit farmers. Establish a demonstration field for papaya fertigation management using existing equipment and design a proper fertigation system that was affordable. In this experiment, installed drip

and micro spray tape irrigation each in a 0.3 hectare net house and placed a set of tensionmeters at 30 cm and 60 cm depth in each net house using the previously mentioned water tensional readings as a guideline for irrigation. Results of the experiment indicated drip irrigation promotes better overall plant growth than micro spray tape irrigation. Growth characteristics including stem circumference, plant height, mean fruit weight and fruit count all exhibited significantly better measurements with drip irrigation (table 1). Although drip irrigation results in a significantly lower content of fruit soluble solids, 11.9° Brix was still achieved (Table 1). The estimated yield for drip irrigation is 114 $t \cdot ha^{-1}$, higher than the 89 $t \cdot ha^{-1}$estimated for micro spray tape irrigation. In addition, water consumption in drip irrigation zone was 40% less than that in the micro spray tape zone in the experiment (table 2). Using drip irrigation will conserve water effectively, increase fertilizer efficiency, save on labor costs and enhance yields. Fertigation is an appropriate choice of method in the management of irrigation and fertilization for the commercial production of papaya in Taiwan.

Table 1. Micro spray tape and drip irrigation on the growth characteristics of papaya 'Tainung NO. 2'.

Irrigation method	Fruit weight (g)	Fruit no.	Total soluble solids (^{O}Brix)	Stem circumference (cm)	plant height (cm)
Micro spray tape	851	58.1	12.4	40.2	217.4
Dripline	907	69.9	11.9	48.1	253.7
T-test	***	***	*	***	***

*,**,***Significant at $P \leqq 0.05$, 0.01, or 0.001, respectively, n=32.

Table 2. Total irrigation volume and cost analysis on drip irrigation and micro spray tape irrigation for papaya

Item	Drip irrigation	Micro spray tape irrigation
Water consumptive (10 months)		
Total irrigation volume (m^3)	1,667	2,770
Equipment cost ($ USD)		

PVC tube and accessories	92	132
Dripline / micro spray tape	293	123
Filter and fertigation system	450	10
Total cost ($ USD)	835	265
Filter and fertigation system not included	385	255

*planting area: 0.3 hectare per zone

Teaching and promoting techniques in fertigation for fruit trees

Educate farmers about fertigation

Fertilization in Taiwan has mostly been done via broadcasting; the use of liquid fertilizer is uncommon. Therefore, teaching farmers how to use liquid fertilizers is the first step to spreading the concept of fertigation. A fertilizer injecting device can be connected to the front outlet of existing irrigation line where concentrated liquid fertilizer is injected into the line with the help of a pump, thus increasing fertilization frequency. Also, a flow meter can be installed on the irrigation line to help calculate fertilizer concentration. This set-up is cheap and easy to use; the biggest disadvantages are less uniform application of fertilizer and difficulty in calculating fertilizer concentrations.

Hold demonstration events and provide technical manuals

Assist young and inexperienced papaya farmers to enhance yields and increase income by illustrating how to effectively use the fertigation system developed by KDAIRES and using tentionmeter to establish indicators for irrigation. Researchers, water board representative and farmers were gathered at demonstration events where presentations were held on how fertigation improves the effectiveness of fertilizer and water use and helped to achieve uniformity in plant growth, as well as savings on time, labor, and fertilizers. This provided a great channel where the farmers can learn about techniques in fertigation, obtain subsidy, and exchange experiences. In addition to field performance, we keep publishing practical manuals of the design and management of papaya irrigation system. The consult services are free to farmers.

Cooperate with irrigation association to promote fertigation

Fertigation for other crops will be more widely used in the future. Under the guidance of COA policy, various research institutes and universities will continue to study topics related to fertigation. Results from the study will be used by the seventeen irrigation associations in Taiwan to provide training and promote fertigation

with the goals of enhancing effective water use and ensuring stability in crop production.

Conclusion

Precipitation in Taiwan has a rather unequal distribution. On average, around 78% of the precipitation occurs between May and October. In southern Taiwan, almost 90% of the precipitation occurs during the same period. Southern Taiwan is a major region for tropical fruit production; therefore, irrigation management during fruit tree growth is crucial for this area as this would stabilize yields with consistent quality. Experiments with papaya confirmed that using drip irrigation device for fertigation can enhance water use effectiveness, achieve savings on fertilizer and labor and further increase yields. The results conform to the goals set forth by COA to solve the issues of an aging agricultural population and rising costs in fertilizers, as well as to stabilize yields in agricultural products. Budgets for related research will continue to be appropriated and research will expand to include other topics on important tropical fruit tree productions. Joint efforts by research institutes, irrigation associations and the farmers to promote efficient use of irrigation water and stable crop yields will be encouraged.

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