Report as of FY2007 for 2006VI64B: "Development of a water budget for shade-house crops in the U.S. Virgin Islands"

Publications

- unclassified:
  - None as yet.

Report Follows

Problem and Research Objectives

In spite of the favorable conditions to grow horticultural crops throughout the year in the U.S. Virgin Islands (USVI), production is restricted because of water deficit. Rainfall is insufficient to maintain adequate soil moisture levels for crop production particularly during the dry season (December to August). Consequently, crops experience water stress and irrigation needs to be ensured to obtain acceptable yields. Existing ponds and dams in the USVI are insufficient to store water for agricultural purposes and the low quality of underground water restricts production of many horticultural crops. Desalinized sea-water is being use widely for domestic consumption, but is too expensive for agricultural purposes. Rainwater catchments have long been used in the USVI for domestic consumption and appear to be a feasible supply of good quality water for high value horticultural crops. Adoption of ground liners as a rainwater catchments system has been difficult because it requires additional land that is lost for production and the system has been focused to irrigate crops under full sun that require high amount of water.

The water deficit in the USVI horticultural industry can be ameliorated by growing crops under shade since plants require substantially less irrigation water. Crops grown in open fields of a semi-dry tropical climate are subjected to direct sunlight, high temperatures and wind resulting in high crop evapo-transpiration (ETc) and therefore, demanding large amounts of water. In contrast, shade-houses favor plant growth since plants are less stressful: direct sunlight is avoided, temperature is lower, humidity is higher, wind is reduced, and ETc is low. Irrigation water requirement of 23% to 31% pan evaporation has been used for leatherleaf fern grown under 70% light reduction (Stamps, 1995). In addition, water use efficiency increases under shady conditions (Durr and Rangel, 2003; Jifon and Syvertsen, 2003). Excessive shade, however, can be detrimental for crop production because of reduced photosynthesis. This suggests that the USVI horticultural industry may benefit tremendously by the incorporation of shade-houses for a water-sustainable production system. In addition, some high value ornamentals perform better when grown under shady conditions and there is a demand to complement the flourishing tourist industry in the USVI.

This study evaluated water requirements to produce anthurium cut flowers and heliconias under shade conditions in the USVI. The specific objectives of this study are: a) to determine the water use efficiency in crops grown under shade conditions, and b) to determine the optimal shade for production of anthurium and heliconias. Crops were grown in a shade-house with three different shade levels and the irrigation water balance was analyzed and compared with meteorological data. The information obtained in this project will help horticulturists in the USVI develop decision criteria for crop selection and adoption of shade-houses to improve water productivity (WP).

Methodology and Principal Findings

All experiments were conducted at the University of the Virgin Islands Agricultural Experiment Station in St. Croix, VI.

Experiment I

Methodology:

In the first experiment, three water stress levels and two shade levels were studied for Anthurium cut flower production. Irrigation schedule was based on soil moisture levels at -10, -30, and -50 kPa to determine the effect of water stress on water savings and flower production and quality. The shade levels were 60% and 80%. Eight plants were planted on 1.44 m2 beds filled with a base of 20 cm sand topped with another 20 cm soilless media (Promix BX). Three plots (repetitions) were set up for each treatment. Plots were irrigated with micro-sprinklers scheduled to irrigate when soil moisture reached the corresponding treatment level. Soil moisture was monitored by Watermark soil moisture sensors (Irrometer Co., Riverside, CA) and connected to the Watermark Electronic Module (Irrometer Co.) which would allow the solenoid to open for irrigation. Soil moisture, applied water quantity, pan-evaporation, and flower production were monitored from January to April, 2006 to determine water requirements. Rainfall and pan-evaporation from the meteorological station was monitored also. Due to the inconsistency of the Watermark sensor at stressing levels and the low quality of the flowers, the irrigation schedule was changed in May to daily irrigation with fixed amount of water. Treatment consisted in 1.1, 2.2 and 3.3 mm a day for both shade levels. These amounts were approximately 16%, 33% and 50% pan evaporation at full sun. In addition, 2.2 and 3.3 mm correspond to 1.2 times pan evaporation at 80% and 60% shade, respectively.

Principal Findings:

Rainfall was substantially lower than evapo-transpiration particularly during the dry season (January to August) (table 1, fig 1). By the end of April when irrigation scheduling was changed, pan evaporation at 60% and 80% shade was reduced to 47% and 32% of full sun pan-evaporation, respectively, and rainfall was 21% (79% deficit). Similar differences in pan evaporation continued until the end of the experiments in November, however, rainfall deficit was reduced to 53% since the rain was more frequent and heavier. These results suggest that shading is an excellent alternative to reduce crop water requirements in comparison to direct sun production and that it is possible to grow crops in a shade-house modified to catch rainwater and use it for irrigation. In the first period, the automatic irrigation system worked well at -10 kPa allowing irrigation to start. The amount of water applied to the -10kPa treatment at 60% and 80% shade was 66 mm in 4 applications and 33 mm in 2 applications, respectively. In contrast, at lower soil moisture levels the moisture sensors appeared to have lost contact with the media and reading became erratic. In this production period, the number of harvested flowers was slightly lower at 80% shade (fig 2), but flower quality appeared to be superior. In addition, water stress with the purpose of saving water was detrimental on flower production since the number of flowers (and quality) was dramatically reduced (fig 2). In the second production period, there was no difference in production between the amounts of applied water at 80% shade (fig 3). Yield of flowers was higher at 60% than at 80% shade suggesting that 80% shade may have been below the optimum and photosynthesis may have been reduced. Within 60% shade yield was reduced with lower amount of water suggesting that irrigation may have been suboptimal. Therefore, evapotranspiration needs to be satisfied in full for optimum production.

Experiment II

Methodology:

A second experiment was conducted in September – November, 2006 to estimate water requirements and water use efficiency in production of potted anthurium and heliconia under three shade conditions. A greenhouse 20' by 12' was built and separated in four sections with shade levels of 0%, 30%, 50% and 70% (DeWitt Knitted shade cloth, Hummert International, Earth City, MO). Six anthuriums and three heliconias growing in three-gallon black pots were used per treatment. Rainwater collected from the greenhouse's top through gutters was stored and used for drip-irrigation and plants were fertilized by injecting soluble fertilizer (Peters 20-20-20 + micronutrients at 100ppm N). An automatic irrigation systems based on a timer was set up to irrigate pots for 1 min three times a day. Drippers of 2, 1, 0.5, and 0.5$gal \cdot h^{-1}$ were used for 0%, 30%, 50% and 70% shade, respectively. Excess drain water was monitored daily to determine daily water used and pot weigh was monitored once a month. Pan evaporation was monitored at each shade level for comparison with rainfall and pan evaporation from the meteorological station. Temperature, relative humidity and solar radiation were monitored also with a Watchdog mini-datalogger (Spectrum Technologies, Inc., East Plainfield, IL).

Principal Findings:

Water requirements of potted anthurium and heliconia were reduced significantly as shade level was increased from section 1 (no shade) to section 4 (70% shade) (table 2). Similar to pan-evaporation, daily water used by both anthuriums and heliconias was reduced to 21% and 18%, respectively, from no shade to 70% shade. This reduction appears to be the effect of less solar radiation since temperature and relative humidity were similar among the shade levels. Pan evaporation recorded at the shade-house including the non-shaded treatment was lower than pan evaporation at the weather station. 55% reduction in section 1 which was not shaded may have been due to the reduced solar radiation under the plastic top and the more protected conditions that may have reduced the wind effect. Growth of the potted plants was not detected in the shaded treatments. Both anthurium and heliconias did not survive the non-shaded treatment and plants turned yellow and 60 % died during the trial. Three month trial appears to be insufficient to evaluate growth of tropical ornamental under shade conditions. Therefore, a longer testing period is needed to determine water productivity for these crop species.

Conclusions

It may be concluded then that:

- Catching rainwater in a modified shade-house and use it for irrigation may be sufficient to implement a water sustainable production system.

- Increasing shade level reduces water requirements for Anthurium and heliconia production and yield. Anthurium and heliconia are recommended to be grown under 50% - 70% shade to improve growth and the flower quality.
- Stressing plants to save water is not recommended due to reduction of flower production and quality.

SIGNIFICANCE

Development of a water sustainable production system will impact favorably the horticulture industry since water is the most limiting constraint to agriculture in the USVI. Water deficit ranges between 40% and 70% during the dry season in the territory. Production of shade loving crops appears to be an excellent alternative to reduce water requirement and improve water use efficiency and productivity in the USVI. In addition, collection and storage of rainwater will reduce the dependency on costly city water. Rain-water collection and storage has being long adopted in the USVI for household consumption and can be easily adopted to develop a water sustainable production system. Adoption of this system by small-scale growers may increase production of ornamental and specialty crops in the USVI impacting tremendously the local economy.

Table 1

Total Evaporation and Rainfall, St Croix, USVI. January-November, 2006

	Cumulative Pan evaporation	Rainfall	Evap I	Evap II	Percent from pan evaporation		
					Rainfall	Evap I	Evap II
Shade	(Weather station)		80%	60%		80%	60%
	mm	mm	mm	mm	%	%	%
April, 2006	629	135	203	297	21	32	47
Nov, 2006	1824	970	516	862	53	28	47

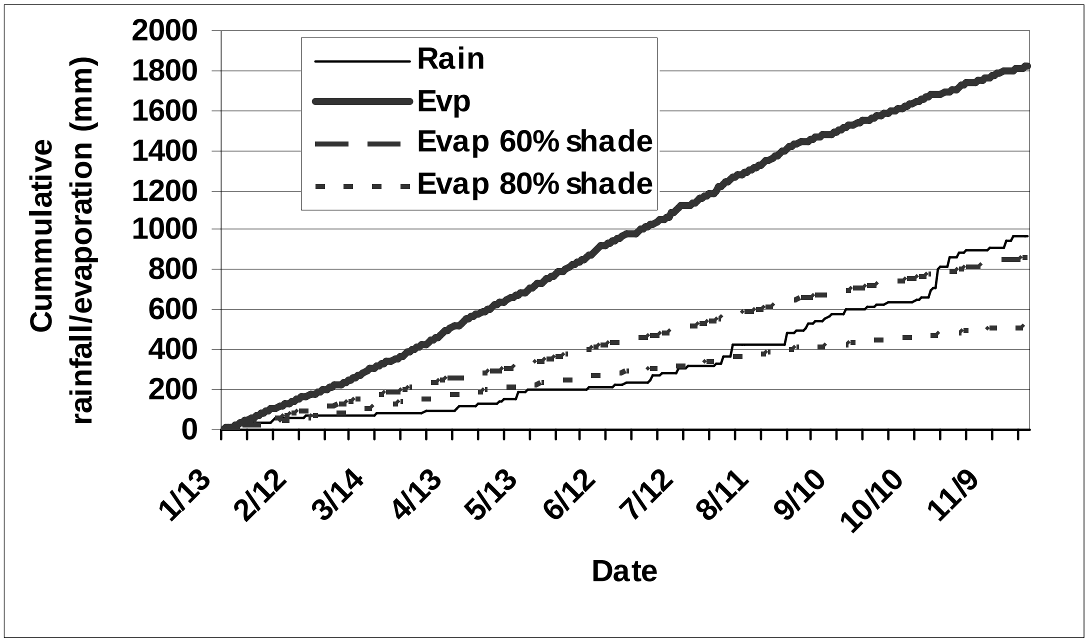

Figure 1

Cumulative Rainfall and Pan-evaporation at Full Sun, 60% and 80% Shade. January – November, 2006, Kingshill, St. Croix, USVI.

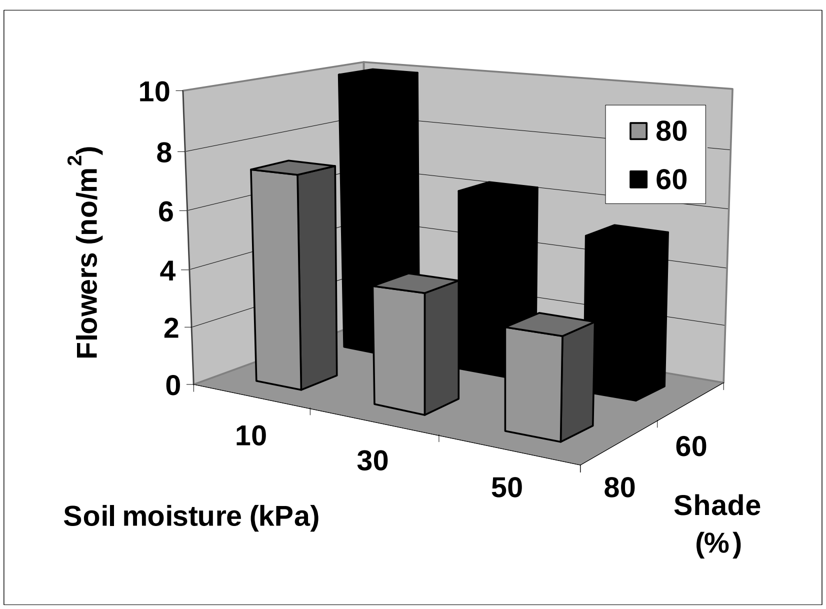

Figure 2. Anthurium production at three irrigation regimes (-10, -30 and -50 kPa) under 60% and 80% shade. Harvest from January to April, 2006. Production plots were 1.44 m^2.

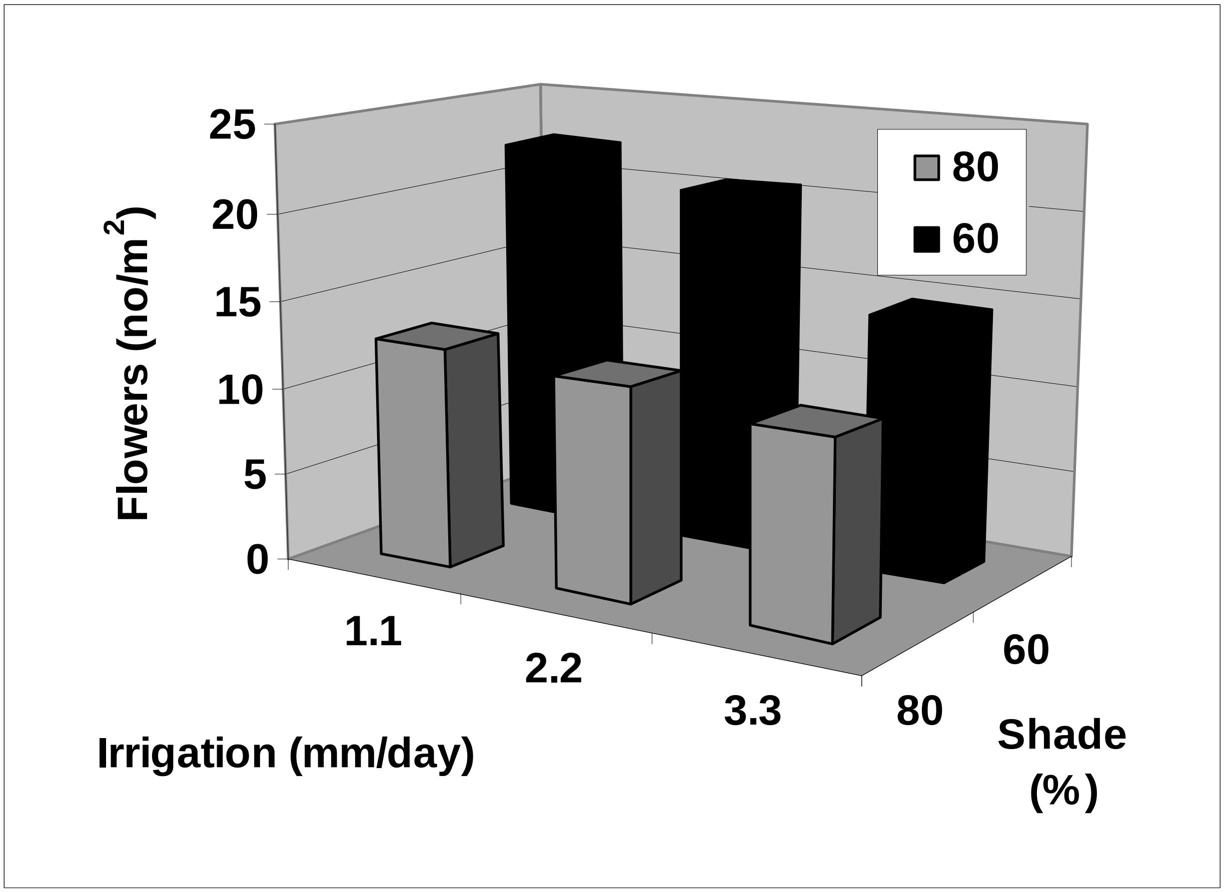

Figure 3. Anthurium production at three irrigation regimes (1.1, 2.2 and 3.3 mm/day) under 60% and 80% shade. Harvest from May to November, 2006. Production plots were 1.44 m^2.

Table 2

Pan-evaporation, water used, temperature (temp), relative humidity (RH), and solar radiation (SRD) in shade-house production of potted anthuriums and heliconias

	Daily pan-	Daily water used / plant				
	evaporation	Anthurium	Heliconia	temp	RH	SRD
	mm	mL	mL	C	%	MJ/m^2/day
Weather station	5.8					
0% shade	3.2	297a	265 a	28.2	77	14.6
30% shade	2.3	150 b	124 b	28.1	78	8.1
50% shade	2.0	75 c	68 c	28.1	78	6.3
70% shade	1.4	62 c	48 c	27.7	81	3.8