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Hair Sheep Performance in an Extensive, Native Pasture System: A Five Year Summary

Stephan Wildeus and Joni R. Collins

The most likely production environment encountered by hair sheep in the Caribbean region is that of a low-input, small scale farming system. Under these conditions, nutrition, management and a lack of genetic diversity become the major constraints to efficient production. In order for an animal to be productive in this type of environment it must successfully cope with these constraints. However, very little research data are available on the productivity of hair sheep under Caribbean conditions and how factors such as ewe age and season affect animal performance.

Among the objectives of the Sheep Research Facility at the Agricultural Experiment Station of the University of the Virgin Islands is to evaluate the production potential of the local hair sheep under a management system typically experienced by these animals. To this end, animals were grazed rotationally on native pasture (grass/legume association) without supplementation. The rate of rotation was based on forage availability. All animals were also confined overnight to control predation and larceny. Ewes lambed without help on pasture and were provided no assistance in mothering up. Anthelmintics were administered routinely at two-month intervals.

Modifications to the traditional system included controlled breeding and weaning (nine weeks after lambing) to facilitate data collection and analysis. The breeding system was based on an eight-month lambing cycle with ewes divided into an A and B flock, bred four months apart in a 34-day single sire mating period. Ewe body weights were recorded at weekly intervals, while lamb weights were recorded within 24 hours of birth and at weaning (63±4 days postpartum).

Under this standardized management system, data were collected over a five-year period (1986-1990). Data (390 records) were analyzed with a statistical model that included year, season of year, parity, litter size and flock as main effects. Parity was assigned into five categories (1st lambing, 2nd lambing, 3rd lambing, 4th-9th lambing and 10th-12th lambing). Season of year was divided into the periods of January to April, May to August and September to December, with lambing concentrated in February/March, June/July and October/November. Litter size was classified as single and multiple types of birth.

> **"Under Caribbean conditions, nutrition, management and a lack of genetic diversity are the major constraints to efficient production."**

There were significant differences in ewe and litter weaning weights between years (Table 1). The most pronounced change occurred from the first to the second year of the study with a general decline in ewe weaning performance. This reduction is most likely the result of a change in age structure of the flock, which started as a foundation flock of mature stock

Table 1. Variations between years in ewe body weight and lamb production in hair sheep ewes on St. Croix.

Criteria	Year				
	1	2	3	4	5
Ewe breeding wt. (lb)	77.4	80.0	83.3	76.7	84.0
Ewe weaning wt. (lb)	86.6	77.6	78.5	76.9	79.4
Lambs born/ewe lambing	1.75	1.63	1.60	1.60	1.77
Litter birth wt. (lb)	11.5	10.8	10.4	10.6	11.2
Lamb survival to weaning (%)	85.5	87.8	88.9	86.2	80.6
Litter weaning wt. (lb)	45.7	34.8	36.4	39.9	43.7

Table 2. Variations between seasons in ewe body weight and lamb production in hair sheep ewes on St. Croix.

Criteria	Season of Year		
	Jan-Apr	May-Aug	Sep-Dec
Ewe breeding wt. (lb)	76.5	81.6	84.2
Ewe weaning wt. (lb)	78.7	86.2	81.4
Lambs born/ewe lambing	1.65	1.66	1.69
Litter birth wt. (lb)	10.5	11.2	10.9
Lamb survival to weaning (%)	87.1	85.9	77.1
Litter weaning wt. (lb)	39.0	40.3	34.2

recruited from a number of local farms into which younger replacement animals were entered in subsequent years. The younger replacement ewes had not reached mature production potential at this point. In the fifth year of the study ewe weaning performance had again reached first year levels and may suggest an overall improvement in flock performance as a result of selection and/or changes in native pasture quality through rotational grazing.

Season of year had a significant impact on ewe performance at weaning, but not at lambing (Table 2). Ewe body weights were lower during the period of January to April compared to the other two seasons. In contrast, survival to weaning was reduced by 10% in lambs during September to December, compared to the remaining two seasons. The reduced lamb survival resulted in a decrease in litter size at weaning, from 1.45 lambs weaned/ewe lambing during January to April and May to August, to 1.31 lambs weaned/ewe lambing in September to December, and decreased litter weaning weight by 5-6 lb. The September to December period generally experiences increased rainfall and is associated with wet and muddy conditions, which appears to be the primary cause of the poor lamb survival, despite the availability of lush pastures.

Ewe performance in relation to parity is summarized in Table 3. Ewe body weight at both breeding and weaning increased gradually throughout first to fourth parity and remained stable thereafter. Ewe body weight at weaning tended to decrease in the older ewes following the ninth parturition. Changes in litter size and litter birth weight with increasing parity mirrored those of ewe weaning weights, with the number of lambs born/ewe lambing increasing from 1.32 at first parturition to 1.83 at a mature level and litter birth weight increasing from 7.8 to 12.4 lb for the same stages. Again, there was a decline in litter size and birth weight as the ewes exceeded their ninth parturition. The increase in litter size at birth with increasing parity is reflected in the incidence of multiple births (Figure 1), shifting from a frequency of 70% single lambs

Figure 1. The effect of parity on the distribution of birth type in hair sheep ewes on St. Croix.

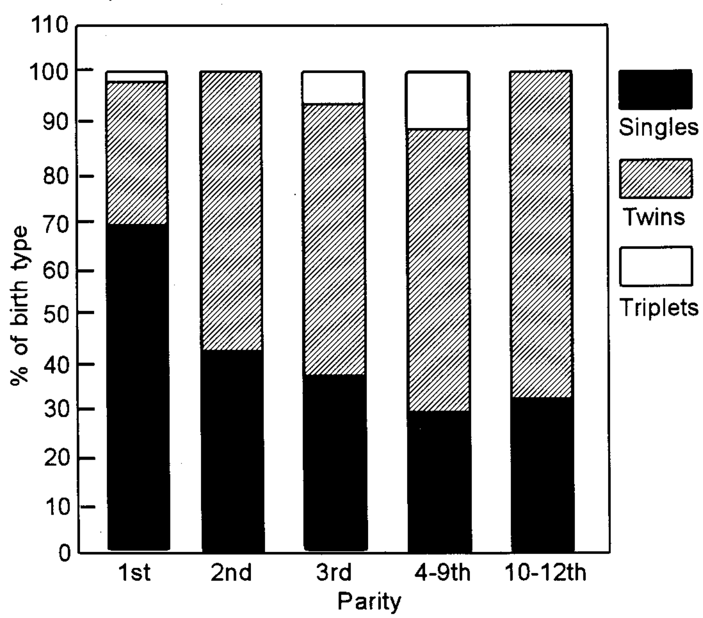

Figure 2. Ewe body weight at breeding and subsequent litter weaning weight in ewes giving birth to singles, twins and triplets.

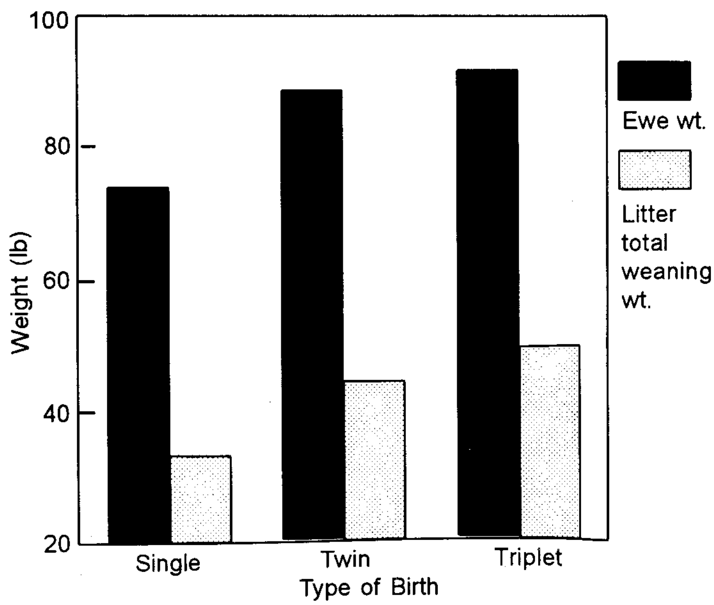

Table 3. Effect of parity on ewe body weight and lamb production in hair sheep ewes on St. Croix

Criteria	Parity				
	1st	2nd	3rd	4th	5th
Ewe breeding wt. (lb)	65.3	74.7	81.6	87.7	87.5
Ewe weaning wt. (lb)	71.2	77.6	81.6	87.7	85.3
Lambs born/ewe lambing	1.32	1.56	1.69	1.83	1.60
Litter birth wt. (lb)	7.8	10.0	10.7	12.4	10.7
Lamb survival to weaning (%)	86.6	82.8	87.1	81.6	73.3
Litter weaning wt. (lb)	32.0	37.0	40.8	39.7	28.4

at first parity to 29% in mature ewes. The corresponding increase in multiple births in the mature ewes was made up of 53% twin and 12% triplet births. No triplet births were recorded in ewes that exceeded their 9th parturition.

Parity in the younger and mature ewes had no effect on lamb survival to weaning which ranged from 82 to 87% (mean 84.5%). However, lamb survival declined by 11% from this mean in the older ewes exceeding nine parturitions. This decline in lamb survival in the older ewes is also reflected in a litter weaning weight 11.5 lb lower than that of mature ewes. Mature ewe weaning performance was achieved with third parity (Table 3).

Ewe body weight at time of breeding had a significant effect on subsequent litter size (Figure 2). To a large degree this effect would be an indirect result of changes in age and parity, particularly in the case of single vs. multiple litters. However, differences in ewe body weight at breeding between twin-bearing ewes (85.3 lb) compared to triplet-bearing ewes (92.3 lb) may indicate a direct effect of body weight/condition on ovulation rate and subsequently litter size. There was a positive relationship between litter size and litter weaning weight (Figure 2), but differences between single and twin litters were more pronounced (11.6 lb) than between twin and triplet litters (2.9 lb). In contrast, other research at this station indicated that short term supplementation immediately prior to breeding ("flushing") had no effect on ovulation rate in hair sheep under these production conditions.

The average ewe body weight at breeding and weaning was 81 and 82 lb, respectively, when accounting for differences in year, season of year and parity structure of the flock. Similarly, overall flock lambing performance was 1.67 lambs born/ewe lambing, with an average litter birth weight of 10.8 lb. Average ewe weaning performance was 1.40 lambs weaned/ewe lambing, with a total litter weaning weight of 40.2 lb. The litter size at weaning reflected a lamb survival of 83.7% from birth to weaning, with approximately 4-5% of these lambs born dead and the remainder dying during the period between birth and weaning.

The overall productivity of the flock was high, considering the limited nutritional and managerial input, and ewes weaned approximately 50% of their body weight at breeding at nine weeks postpartum. The data further indicate that ewes reached their mature production potential following their third parturition and that productivity declined after ten parturitions. The latter would be linked to the relatively harsh production environment and the short lambing interval of eight months, although other data from this station indicate that the ewes resume cyclic activity within one to two months postpartum and thus reproductively support this production system.

There was very little evidence of seasonal effects on productivity of the flock with the exception of poor lamb survival to weaning during wet season conditions. Ovulation rate and rebreeding were not affected by season, which is known to influence the performance of sheep under more temperate production environments. Subsequent work at this station has indicated some seasonal effects on the onset of puberty and the length of the postpartum interval in hair sheep under the environmental conditions on St. Croix, but these would not be expressed under the production system applied here.

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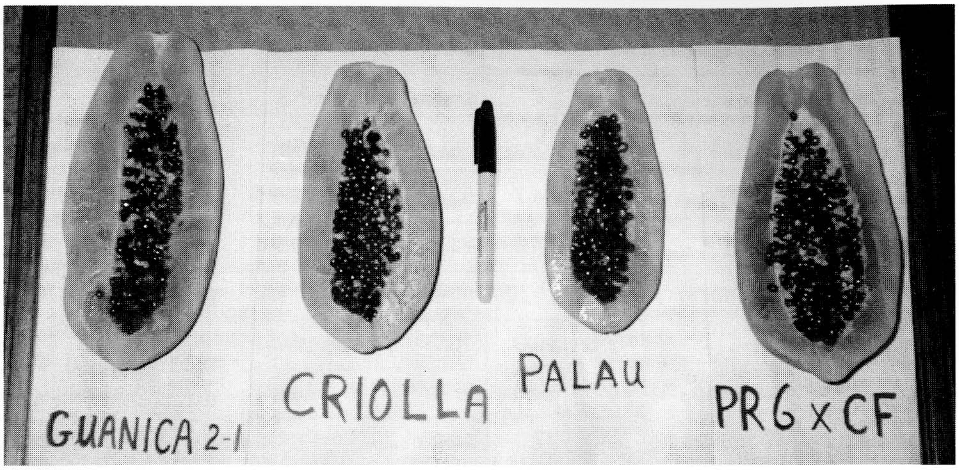
Sustainable Strategies for Reducing Papaya Disease Problems in the U.S. Virgin Islands

Christopher Ramcharan



In the U.S. Virgin Islands, papaya (*Carica papaya* L.) is a unique tropical fruit with good domestic and export market potential to the U.S. mainland, Canada, Europe and Japan. Excellent potential for development exists locally with an expanding tourist market.

There is also a certain amount of versatility in the use of papaya. Besides consumption as a fresh fruit, several processed papaya products can be developed, and papayas are used in both the ripe and green forms in various ethnic cuisines.

Since the early 1960s when a small but ambitious program for the production and export of papaya was initiated on St. Croix, disease problems have decimated production and inhibited export of the fruit. This early program, however, was based solely on the Hawaiian Solo cultivar, which performs well only within a narrow ecological niche.

Major Disease Problems

The two primary diseases affecting papaya in the U.S.V.I. are Papaya Ringspot Virus (PRV) and Bacterial Stem Canker (BSC). While the former is probably of worldwide importance, BSC has been identified only in certain regions, most of which possess climatic and soil conditions similar to those on St. Croix. For example, while BSC is prevalent on islands like Antigua which have agroecosystems similar to St. Croix's, the disease never occurs in papaya plants of the geographically closer but ecologically different island of Puerto Rico. Soil type and rainfall patterns of Puerto Rico differ greatly from St. Croix's, without the consequent environmental stress conditions.

Infected plants are characterized by oily translucent spots or lesions on leaf petioles or stem of the top third of the plant. These enlarge or coalesce to form a stem canker, weakening the stem which may eventually become decapitated. The incidence of BSC also appears to be stress-related, particularly drought and soil-nutrient stresses, with certain cultivars such as the Hawaiian Solo being more susceptible than the Barbados Solo. The combination of water stress and high soil pH-induced nutrient deficiencies also make otherwise resistant cultivars susceptible to BSC.

Papaya Ringspot Virus is a more ubiquitous disease problem and occurs in ecosystems as diverse as those in the Hawaiian islands to those in the U.S. Virgin Islands. The major cause for this widespread incidence is that PRV is aphid-transmitted by the vector *Aphis gossypii*. Several other agricultural crop species, notably the cucurbits, are hosts for PRV. The symptoms caused by PRV include mottled and distorted leaves, ring spots on the fruit, and water-soaked streaks on stems and petioles.

Unlike BSC, the PRV-infected papaya plant can often withstand or sometimes even outgrow the effects of the virus, depending on cultivar and plant vigor (Cariflora cv. is an example). In most cultivars, however, infected plants have an unhealthy appearance, gradually decline and produce infected and blemished fruits with drastically reduced market value. While one or two harvests can sometimes be obtained from PRV-infected plants, BSC usually terminates all production and results in stem collapse and death of the plant.

Control Strategies

In-depth research at UVI-AES in 1985-86 elucidated an *Erwina* sp. of bacteria as the pathogen causing BSC. Succulent-stem type cultivars such as the Hawaii Sunrise Solo, when cultivated under dry, windy and high pH soil conditions, become easy targets for this pathogen (cultivars such as the Barbados Solo with a more woody stem exhibit greater tolerance to BSC by usually outgrowing initial leaf or stem infections). Under these environmental stress conditions, cellular and plant tissue breakdown of succulent cultivars

Table 1. Evaluation and rating of selected papaya cultivars under an integrated production system.

Cultivar	PRV[1]	BSC[1]	High pH[1]	Fruit bearing[2]	Comments[3]
Cariflora	R	T	T	E	Early low-bearing, short SL, good processing potential.
Criolla	R	T	T	L	Tall, late-bearing, large non-uniform fruits, good SL.
Guanica	S	T	T	M	Drought tolerant, prolific, pear-shaped, pink-fleshed fruit.
PR6-65	FT	T	T	M	Pear-shaped, yellow-fleshed firm fruit, good SL.
PR6-65 X Cariflora	T	T	T	M	Pink-fleshed, both ovoid and elongate fruits, good SL.
Solo SR X Cariflora	FT	T	T	M	Solo-shaped, pink-fleshed, prolific.
S-64	S	T	T	E	Low-bearing, very large pear-shaped fruit, few seeds.
Barbados Solo	FT	T	T	M	Pear-shaped firm fruit, good SL.
Palau	S	S	S	M	Small, elongate firm orange-fleshed fruit.

1. R = Resistant; T = Tolerant; FT = Fairly tolerant; S = Susceptible.
2. E = Early; M = Medium; L = Late.
3. SL = Shelf Life.

occur more easily and rapidly, thus facilitating bacterial entry and infection.

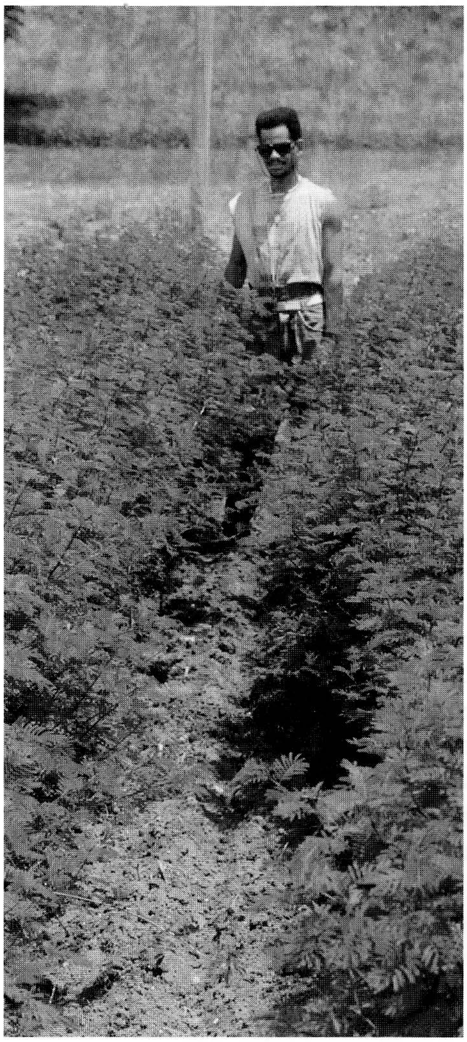
Research conducted by UVI-AES in 1986 on container-grown papaya plants under greenhouse conditions demonstrated conclusively that bacterial infections occurred only when *Erwina* inoculum was sprayed onto bruised leaves. This clearly indicated that plant injury, whether physically or physiologically induced, was essential for the bacterial infection causing BSC in papaya. Field trials conducted during the same years indicated that polyculture or intercropping papaya with other crops, such as pigeon pea, banana and cassava, significantly reduced disease incidence.

More recent studies initiated in 1989 involving intercropped banana and papaya cultivars adapted to local soil and climatic conditions have shown no incidence of BSC. Intercropping with plantain and the use of *Moringa* (horse radish tree) windbreaks have also delayed and reduced the incidence of PRV. These two sustainable cultural practices apparently act by reducing actual wind-induced physical damage to plants, filtering off bacterial inoculum and deterring the buildup of virus-carrying aphids. These are in addition to the physiological advantages of reducing ambient moisture stress, thus decreasing excessive transpirational water loss in papaya plants and increasing water use efficiency. In a broad-leaved plant such as papaya, this is critical to maintaining turgidity in leaves and essential for reducing stomatal resistance and increasing photosynthetic activity.

An ongoing UVI-AES trial with ten papaya cultivars for evaluating production methods has incorporated even more sustainable cultural practices, including minumum tillage, a permanent orchard sod cover, judicious use of herbicides and *Leucaena* and *Moringa* windbreaks. After almost four years of continuous production, no papaya trees have been lost to BSC, and only in the last year has there been a gradual buildup of PRV infection. The cultivars with the best overall performance under such an integrated system are included in Table 1.

While a system of intercropping with the use of windbreaks and integration of certain cultural practices has virtually eliminated the incidence of BSC in papaya in the U.S.V.I. (Table 1), PRV continues to be a major problem. The selection, breeding and evaluation of virus-tolerant cultivars will continue to be major strategies for controlling PRV. Recently, biotechnology has been used to genetically engineer virus-resistant plants to the Hawaiian strain of PRV. This offers an exciting new phase in plant protection, and, to this end, the recently established biotechnology laboratory at UVI-AES has as one of its major objectives to genetically engineer papaya plants with resistance to the Caribbean strain of PRV.

This research was funded in part by Hatch Project No. 0156331.



Desmanthus, a Legume for Forage Production in the Caribbean

Martin B. Adjei

Table 1. *Desmanthus virgatus* accessions subjected to clipping defoliation on St. Croix (1990-92).

VI accession number	Origin
1	St. Croix
2	Venezuela
3	Venezuela
4	Venezuela
5	Venezuela
6	Venezuela
7	Venezuela
9	St. Croix
11	Dominican Republic
12	Dominican Republic
14	Dominican Republic
15	Dominican Republic
16	Dominican Republic
17	Dominican Republic
18	Dominican Republic
20	St. Croix
22	Antigua
23	Venezuela
24	Venezuela
25	Venezuela
26	Mexico (CPI 92802)
27	Mexico (CPI 92803)
28	St. Croix

In the Caribbean, predominant tropical grasses such as guinea grass (*Panicum maximum*) produce large quantities of biomass that are usually low in protein. Investments in fertilizer, especially N, P, and K, can help improve the protein status of tropical grasses. However, tropical grasses seldom exceed 10-12% protein levels, and these levels usually occur at young physiological ages when yields are very low. Confined livestock feeding operations, dairies and feedlots within the region need feed stuff that is high in protein. This need would be reduced if high-yielding legumes adapted to the environment were selected.

The genus *Desmanthus*, of the Leguminosae subfamily Mimosoideae, includes tropical species with a center of origin in the Caribbean basin. Ecotypes range from 2 m high *D. virgatus* shrubs to the prostrate *D. depressus*. They are adapted to alkaline clay soils and occur naturally on many Caribbean grassland sites where they contribute to the diets of grazing livestock. *Desmanthus* is characterized by bipinnate leaves with leaflets less than 10 mm in length. Although in the same subfamily of legumes as *Leucaena*, *Desmanthus* is a much smaller plant with very little aggressive tendency to invade and dominate an entire pasture. Progress is being made in the selection of *Desmanthus* varieties with superior agronomic traits for forage production at the Virgin Islands Agricultural Experimental Station on St. Croix.

The initial screening of *Desmanthus* for their forage potential on St. Croix began in 1988. It included 35 collections of two species (*D. virgatus and D. depressus*) representing a wide range in area of origin and growth habit. Seedlings were transplanted on 1 m centers and evaluated as spaced plants. Although most accessions grew vigorously prior to defoliation, only five accessions continued to maintain vigorous growth following five successive harvests at 90-day intervals.

In 1989, growth from the initial planting was accumulated and subjected to mob-grazing three times (April, mid-July and late October) to gauge their acceptability to sheep and response to grazing. Herbage of the erect accessions near shoulder high was grazed first. Prostrate accessions were grazed later. Animals readily and selectively grazed leaves, immature stems and green pods.

> **“Results obtained so far indicate *Desmanthus* to be an outstanding forage crop with good quality when grown under natural Caribbean conditions.”**

Two accessions—VI 26 (also identified as CPI 92802 or CF 495) and VI 27 (CPI 92803 or CF 543), both originating from the Yucatan of Mexico—were superior in initial growth rating, herbage yield and final persistence. Accessions VI 26 and VI 27 were also the most vigorous following grazing.

From May, 1990, to March, 1992, plots of 23 *Desmanthus virgatus* accessions (Table 1), established from reseeding of the original planting, were further subjected to prolonged clipping

Figure 1. Mean annual total dry matter and edible dry leaf yields of *Desmanthus* accessions from three harvests on St. Croix (1990-92).

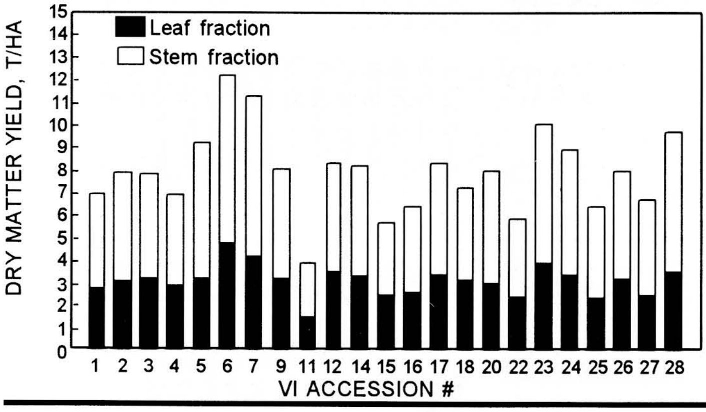
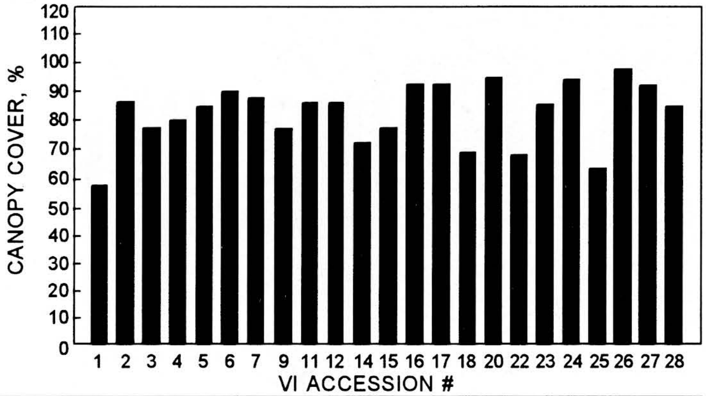
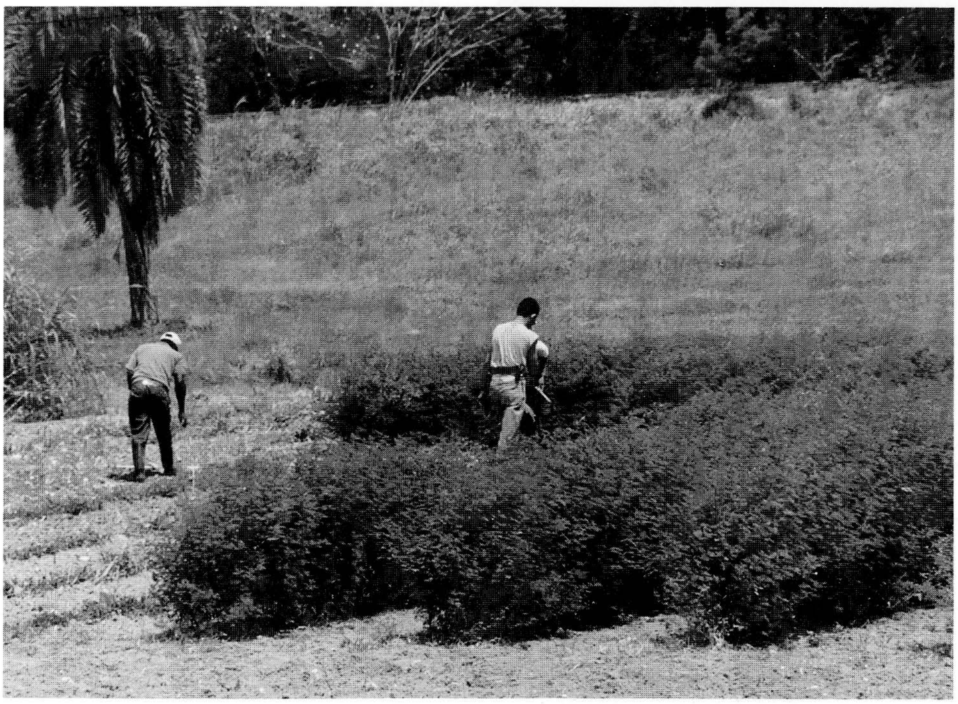


Figure 2. Canopy ground coverage on 2 m^2 plots of *Desmanthus* accessions at the final (March, 1992) of six successive harvests on St. Croix.



management to evaluate their forage yield potential, forage quality and stand persistence. This study was conducted on Fredensborg silty clay loam which had a pH of 7.8. There were three replicates of each entry arranged in a randomized complete block design. As a low-input trial, plots were neither irrigated nor fertilized. Six successive harvests (three per year) were removed from plots (1 m x 2 m) whenever the median of all accessions attained the early-pod stage of maturity. Harvested subsamples were separated into leaf (including young stems and green pods) and stem components, dried and weighed. Selected accessions were analyzed for crude protein (CP) and *in vitro* organic matter digestibility (IVOMD). Prior to the final harvest in March, 1992, the canopy groundcover for each plot was estimated with a divided 1 m quadrat (100 divisions).

Accessions differed significantly in total dry biomass and edible leaf forage yield (Figure 1). Three accessions (VI 6, VI 7 and VI 23), originating from Venezuela, had the highest mean annual dry, leafy forage yield of 4-5 tons/ha. Most of the remaining accessions produced 3 tons/ha leafy forage, yearly, except for VI 11 which yielded less than 2 tons/ha. However, the two earlier selections from the Yucatan of Mexico, VI 26 and VI 27, were among the most persistent entries as determined by canopy ground coverage of approximately 95% at the final harvest (Figure 2). Crude protein content of *Desmanthus* leaves was consistently high, ranging from 18 to 21% of dry matter (Figure 3). However, crude protein content of stems averaged only 8%. This suggests a necessity to select and manage *Desmanthus* forage crop for a higher leafy component in future studies. The leaf IVOMD of all accessions evaluated was above 80% (Figure 4). The data indicate the possibility to select accessions with a potential production of 3 to 5 tons/ha dry, edible leafy forage annually, when *Desmanthus* is harvested at the early pod stage of maturity. Such forage should be highly nutritious to livestock, containing approximately 20% CP and 80% IVOMD.



The results obtained so far on *Desmanthus* indicate it to be an outstanding forage crop with good quality when grown under natural Caribbean conditions. Our preliminary feeding trials also suggest a more favorable hair sheep growth response to diets derived from grass/*Desmanthus* combination than from grass alone.

Desmanthus is readily established from seed that is commercially available at the Caribbean Agricultural Research & Development Institute (CARDI) in Antigua. The initial seed multiplication by CARDI was contracted jointly by the University of the Virgin Islands and University of Florida with *Desmanthus* selections from St. Croix. Hard-seededness is a characteristic of the genus. The outcome of evaluation of methods of scarification on St. Croix is

Figure 3. Crude protein as a percentage of dry matter in stems and leaves of *Desmanthus* accessions on St. Croix (1990-92).

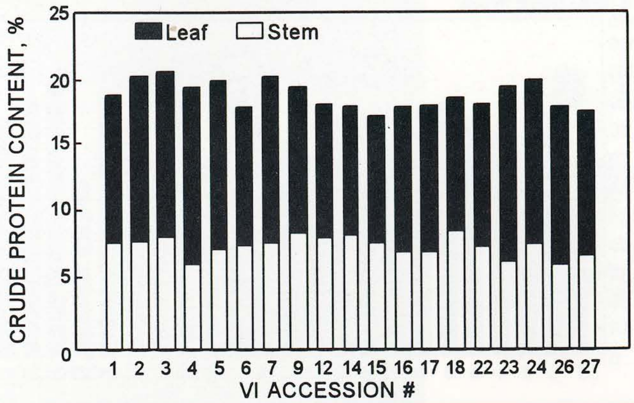
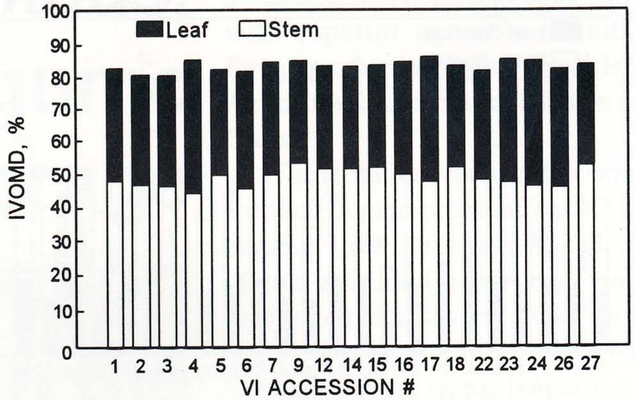


Figure 4. *In vitro* organic matter digestibility of stems and leaves of *Desmanthus* accessions on St. Croix (1990-92).



that *Desmanthus* seed should be soaked in 70 °C water for one minute and then dried to improve germination. Planting should be done in well-prepared, moist seed bed at a seeding rate of 6 kg/ha. Good soil moisture availability during the initial two post-planting months ensures quick establishment and minimum weed problems. Three annual harvests at the early-pod stage of maturity are recommended for cut-and-carry forage management. Grazing management strategies for sustained *Desmanthus* pasture production are currently being investigated on St. Croix.

A high level of interest in *Desmanthus* forage for alkaline, clay soils continues to be shown among researchers and graziers in tropical America, Australia and Africa. Present collections of *Desmanthus* in repositories include almost 300 accessions at CSIRO, Australia; over 150 accessions at CIAT, Colombia; and smaller collections at ILCA, Ethiopia; CARDI, Antigua; and the USDA. Recently, three cultivars were commercially released by Wright Stephenson Seed Co. of Queensland, Australia, at the 1993 International Grassland Congress. Clipping and grazing defoliation management information being generated by UVI-AES on St. Croix will contribute to Caribbean forage programs.

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Improving Culinary Herb Production with Drip Irrigation in the Virgin Islands

Manuel C. Palada, Stafford M.A. Crossman and Charles D. Collingwood

Culinary herbs are important horticultural crops in the Virgin Islands. An informal survey conducted in 1988 revealed that sales of herbs and spices constitute a major source of income for many small-scale growers in St. Thomas and St. Croix.

Herb production in the Virgin Islands mainly supplies the local market. A small percentage is exported to the U.S., while most of the herbs consumed in the U.S. are imported from the Mediterranean region, Africa and Latin America. Improving field production of herbs in the Virgin Islands will increase its potential for the export market and at the same time improve the local economy.

Although most culinary herb species and varieties are easily adapted to the tropical climate of the Virgin Islands, field production is constrained by environmental factors and management practices. Water is a major limiting resource for agriculture in the Virgin Islands, and without supplemental irrigation, commercial production of high value crops such as herbs is not economically feasible. The traditional practice of growing herbs in the Virgin Islands requires frequent watering with sprinkler cans and garden hoses. This practice is inefficient and involves high labor and water use.

Drip irrigation was first introduced to the Virgin Islands in the early 1980s. Studies at UVI-AES indicated that drip irrigation has more advantages compared to the traditional practice of supplying water to the crops, in terms of labor, water use, efficiency and cost. Many growers are now considering a drip irrigation system an essential component of their vegetable production enterprise.

At UVI-AES, a research project was initiated in 1988 to improve field production of herbs through efficient water use and optimum fertilizer application. The application of drip irrigation technology was subsequently extended to herb production throughout the Virgin Islands. This report presents the results of drip irrigation experiments with basil (*Ocimum basilicum*) and thyme (*Thymus vulgaris*).

Two field experiments were conducted to 1) determine the response of thyme to irrigation methods and rates and 2) determine the water requirements of thyme. In the first experiment, thyme seedlings were started in seedling trays and grown in the greenhouse in March, 1991. At 45 days after sowing, seedlings were transplanted in field plots that were 9.4 feet long and 7.4 feet wide. Each plot contained three rows 30 inches apart. Seedlings were planted at a spacing of 12 inches in the row.

Irrigation treatments consisted of two methods (drip versus micro-sprinkler) and two rates based on pan evaporation (40% PE versus 60% PE). Pan evaporation is the amount of water that is lost through evaporation from a standard Class A circular pan measuring 46.5 inches in diameter and 10 inches deep. Half of the plots in treatment under drip irrigation were covered with 1 mil (0.025 mm) black plastic mulch. None of the plots under micro-sprinkler irrigation were mulched.

The drip irrigation system consisted of main and submain lines made of 0.6-inch (15 mm) polyethylene hose, and the laterals were made of 0.6-inch (15 mm) drip strip with laser-drilled orifices 12 inches apart. The micro-sprinkler system consisted of 0.6-inch polyethylene hose with micro-sprinklers attached to the laterals in center rows. The experiment was arranged in a randomized complete block design with six treatments and three replications. The experiment was conducted from March to September, 1991.

Data presented in Table 1 show that under drip irrigation, fresh yield of thyme in plots without plastic mulch was higher than with mulch. The difference in yield between the two rates of irrigation (40% PE vs. 60% PE) was not statistically significant either in mulch or no mulch

Table 1. Yield of thyme under two methods and rates of irrigation. UVI-AES, 1990.

Irrigation system	Irrigation Rate (% PE[2])	Mulch	Fresh leaf yield[1] (t/ac)
Drip	40	No	3.57a
Drip	40	Yes	1.34c
Drip	60	No	3.75a
Drip	60	Yes	2.32bc
Sprinkler	40	No	2.05bc
Sprinkler	60	No	3.04ab

[1]Values within a column followed by the same letters are not significantly different by Duncan's Multiple Range Test, ($P<0.05$).
[2]Pan evaporation.

Table 2. Plant height, total plant fresh and dry matter yield of thyme grown at three levels of drip irrigation with and without mulch. UVI-AES, 1992.

Irrigation level (cb)	Mulch	Plant height[1] (in)	Plant Yield[1] Fresh (lb/ac)	Plant Yield[1] Dry (lb/ac)
20	No	8.03a	4436a	1432a
40	No	7.87a	2647b	884b
60	No	7.60ab	3121b	1044ab
20	Yes	5.98b	2013bc	597bc
40	Yes	6.42ab	1799bc	571bc
60	Yes	6.73ab	963c	296c
Rainfed	No	6.57ab	2479b	876b

[1]Values within a column followed by the same letters are not significantly different by Duncan's Multiple Range Test, ($P<0.05$).

Table 3. Estimated irrigation water use and efficiency of thyme at three levels of irrigation with and without mulch. UVI-AES, 1992.

Irrigation level (cb)	Mulch	Total water use (gal/plt)	Total water use (ft³/ac)	WUE[1] (lb/ft³)
20	No	1.55	7036	0.63
40	No	1.19	5406	0.49
60	No	0.48	2160	1.44
20	Yes	1.55	7036	0.29
40	Yes	1.19	5406	0.33
60	Yes	0.48	2160	0.45
Rainfed	No	4.33[2]	19621[2]	0.13[2]

[1]WUE= water use efficiency in pounds dry matter per cu. ft.
[2]Represents amount of rainfall based (1 inch rain = 27,000 gallons/acre).

Table 4. Estimated cost of irrigation water and efficiency in thyme production with drip irrigation. UVI-AES, 1992.

Irrigation level (cb)	Mulch	Irrigation water cost[1] ($/ac)	Returns to irr. water[2] ($/$)
20	No	844	70.62
40	No	649	54.80
60	No	259	161.93
20	Yes	844	32.04
40	Yes	649	37.57
60	Yes	259	44.95

[1]Based on water cost of $0.12/cu.ft.
[2]Dollar return to every dollar spent in irrigation water.

treatment. Under micro-sprinkler irrigation, fresh yield of thyme at an irrigation rate of 60% PE was numerically higher than at 40% PE. However, the yield at 60% PE was similar with those obtained from drip-irrigated treatments without mulch.

The lower yields from drip-irrigated plots with black plastic mulch and those under micro-sprinkler irrigation were attributed to the high incidence of fungal diseases. Wet soil in plots with plastic mulch and frequent wetting of foliage in sprinkler-irrigated plots may have contributed to favorable development of soil-borne fungus diseases including *Phytophthora sp.*, *Phythium sp.*, and *Rhizoctonia solani*.

Results of this experiment indicate that improved yield of thyme was achieved under drip irrigation without mulch. This method has the added advantage of allowing growers to cultivate and mound the soil around the plant for better plant growth. The micro-sprinkler method is not only inefficient, but also requires high volumes of irrigation water since part of the water applied is lost through evaporation and spray drift.

The second experiment was conducted to determine the irrigation water use and requirement of thyme with and without mulch. The treatments consisted of three irrigation levels corresponding to soil moisture tension of 20, 40 and 60 in centibars (cb). A centibar is a unit used to measure the amount of pressure by which the soil particles hold water or moisture. The higher the pressure the lower the amount of water or moisture available to plants. Soil moisture tension is measured by using a device called a soil tensiometer. Half of the plots were mulched using a black plastic, water-permeable weed barrier ground cover. A rainfed control (no mulch) was included as a treatment.

Thyme seedlings were transplanted on March 20, 1992, in three-row plots arranged in a randomized complete block design with four replications. Plot size measured 3 feet x 8 feet. Plants were spaced 12 inches between rows and 8 inches between plants within rows. The plants were fertilized with nitrogen, phosphorus and potassium at the rate of 45, 90 and 90 lb/ac, respectively.

The fertilizer was applied one week after transplanting. The drip irrigation system installed in plots was similar to that in the first experiment. Soil tensiometers were installed at a 6-inch depth in each treatment on two replications to monitor soil moisture tension. The tensiometers were read daily and irrigation was turned on when readings were above a prescribed centibar treatment. A water meter and timer were also installed for each treatment. Data were collected on plant height at harvest, plant fresh weight yield and dry matter weight. Total irrigation water use was determined over a period of nine weeks.

High rainfall during the growing season confounded the results of the trial. Over a period of three months (April to June) total rainfall was 13 inches (Figure 1). May was the wettest month with rainfall of 11 inches. Despite the high rainfall, differences in yield among treatments were significant (Table 2). Total plant fresh yield was highest (4436 lb/ac)

Figure 1. Rainfall and potential evapotranspiration at UVI-AES, 1992.

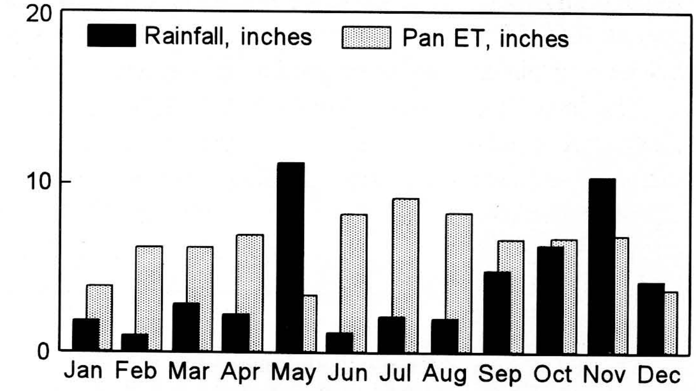


Table 5. Plant fresh yield of drip-irrigated basil grown with organic and synthetic mulches. UVI-AES, 1991.

Mulch	Harvest 1st	2nd	3rd (yield, t/ac)[1]	4th	Total
Compost	2.2	5.2	10.5a	10.4a	28.4a
Grass straw	1.8	3.8	5.7b	8.2ab	19.6b
Black plastic	2.5	5.3	9.2ab	7.1ab	24.2ab
Weed barrier	2.4	5.0	6.2b	4.6b	18.3b
Control (no mulch)	1.9	4.8	8.4ab	5.0b	20.3b

[1]Values within each column followed by the same letter are not significantly different by Duncan's Multiple Range Test, ($P<0.05$).

from the treatment with an irrigation regime maintained at 20 cb without mulch. Dry matter yield was also highest for this treatment, but not significantly different from the treatment under an irrigation regime of 60 cb. Generally, all treatments with mulch and the control (rainfed) had lower yields than irrigation treatments without mulch. This result is consistent with those obtained in the first experiment and would indicate that mulching is not beneficial for thyme. Furthermore, when soil moisture is not a limiting factor because of high rainfall, mulching is no longer an advantage.

Total irrigation water use was highest in treatments with an irrigation regime of 20 cb (Table 3). Treatments under 60 cb had the least water use. However, only the treatment at 60 cb without mulch resulted in more efficient use of irrigation water at the least cost (Table 4). This result would suggest that under high rainfall, supplemental irrigation can be reduced by maintaining the soil moisture at 60 cb. At this level the minimum water requirement of thyme can be met. However, during seasons of low rainfall this level may change.

Although thyme does not respond favorably to mulching as shown in the two experiments, integrating drip irrigation with mulching can further conserve water by reducing water use, evapotranspiration and weed control and by increasing overall water use efficiency for other crops. The choice of mulching materials may also influence the response of herb species to drip irrigation.

In the summer of 1991 an experiment was initiated to 1) determine the effect of various mulching materials on yield and water use of basil under drip irrigation and 2) compare water use efficiency of basil grown with organic and synthetic mulches.

Basil was grown in plots with organic (compost or grass straw) and synthetic (black plastic or weed barrier ground cover) mulches. The compost was prepared using a 1:1 ratio of sheep manure and vegetable crop residues. The grass straw was made of dry pangola grass. The compost and grass straw mulches were applied at 2 inches thick. A control plot (no mulch) was also included as a treatment. Plot size was 4 feet x 7 feet with rows 16 inches apart. Plants were planted at 12 inches spacing within rows. The experiment was arranged in a randomized complete block design with four replications. All plots were drip-irrigated to maintain soil moisture at 30 cb. The drip irrigation system installed was similar to that of the 1991 experiment on thyme. The amount of irrigation water used was monitored with water meters installed for each treatment.

Data on Table 5 show that plant fresh yield did not vary significantly among treatments during the first and second harvests. Differences in yield were observed in the third and fourth harvests. At the third harvest, basil grown with compost mulch produced the highest yield of almost 10.5 t/ac. This was followed by plants with black plastic mulch and the control. Basil grown with grass straw and weed barrier ground cover produced lower yields. At the

Table 6. Irrigation water use of basil grown with organic and synthetic mulches. UVI-AES, 1991.

Mulch	Total fresh yield (t/ac)	Total water use (ft^3/ac)	WUE[1] (lb/ft^3)
Compost	28.4	22719	1.25
Grass straw	19.6	21091	0.93
Black plastic	24.2	24877	0.97
Weed barrier	18.3	18390	1.00
Control	20.3	21634	0.94

[1]WUE = water use efficiency (lb fresh basil per cu. ft. water).

Table 7. Yield and economic returns from drip-irrigated basil grown with organic and synthetic mulches. UVI-AES, 1991.

Mulch	Total yield (t/ac)	Gross value[1] ($/acx1000)	Irr. water cost[2] ($/ac)	Returns to irr. water[3] ($/$)
Compost	28.4	113.6	2726	41.6
Grass straw	19.6	78.4	2531	31.0
Black plastic	24.2	96.8	2985	32.4
Weed barrier	18.3	73.2	2207	33.2
Control	20.3	81.2	2596	31.3

[1]Fresh basil at $4.00/lb.
[2]Irrigation water at $0.12/cu.ft.
[3]Dollar return for every dollar spent on irrigation water.

"Although basil grown with compost mulch used more water than other treatments, yield and water use efficiency were the highest, resulting in higher gross returns."

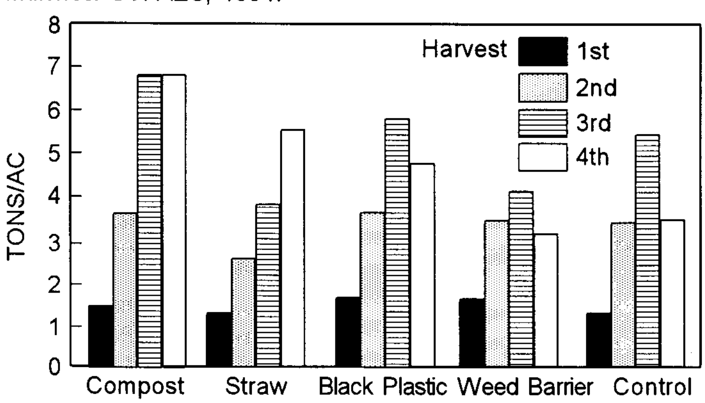
fourth harvest, basil grown with compost mulch maintained the highest yield. Total yields of basil grown with compost mulch were significantly higher than the other treatments with the exception of the black plastic mulch.

Differences observed in plant fresh yield were also reflected in leaf fresh yields. The treatment with compost mulch produced the highest fresh leaf yield, followed by the treatment with black plastic mulch (Figure 2).

Total water use was highest in plots with black plastic mulch (15% more than the control), followed by compost mulch which was 5% more than the control (Table 6). Grass straw and weed barrier ground cover reduced water use by 3 and 15%, respectively.

The high water use in plots with black plastic mulch may be associated with high soil temperature (data not shown) which may have induced rapid loss of soil moisture. In compost-mulched plots large water use may be associated with high water absorbing capacity of compost material which acted like a sponge. Low irrigation water use in the control

Figure 2. Fresh leaf yield of basil grown with organic and synthetic mulches. UVI-AES, 1991.



plots can be explained by the addition of rainfall which totalled 13 inches during the five-month growing season (March to July).

The higher yield from the treatment with compost mulch can be partly explained by possible leaching of nutrients from compost down to the root zone. During decomposition of compost materials, nutrients are released slowly and become available to plants. Nutrient contribution from the compost material may have increased towards the latter part of the growing season as shown by the higher yield of the final two harvests.

Although basil grown with compost mulch used relatively more water than other treatments, yield and water use efficiency were also the highest. This resulted in higher gross returns and returns on irrigation water (Table 7). At a $4.00/lb wholesale price of fresh basil, treatment with compost mulch gave the highest gross return of $114,000/ac. If herb growers have to pay for irrigation water at $0.12/cu ft., using compost mulch will give them the highest returns on irrigation water of $42 for every dollar spent.

This study has shown that compost mulch increased basil yield, improved water use efficiency and boosted economic returns to irrigation water. Integrating compost mulch with drip irrigation for basil production offers some economic benefit for small-scale herb growers in the Virgin Islands. Organic mulches such as compost and grass straw are locally available, thus saving herb growers the cost of importing expensive synthetic mulches.

The only drawback of using organic mulches is the potential weed problem associated with either compost or grass straw material. If the mulch is made from materials containing viable weed seeds, weed growth can be a problem.

The results of experiments on thyme and basil also suggest that the response of herb species to mulching is variable. Basil responded favorably to mulching while thyme did not. Additional studies are being carried out at UVI-AES to investigate the response of other herb species to drip irrigation and mulching.

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Comparison of Tilapia Species for Cage Culture in the Virgin Islands

James E. Rakocy, John A. Hargreaves and Donald S. Bailey

Tilapia is a tropical fish native to Africa and the Middle East. Since tilapia is a hardy fish that feeds low on the food chain and is relatively easy to culture, it has been distributed widely throughout tropical countries to increase protein supplies. Tilapia is also being cultured in many temperate countries in heated or geothermal water because its delicious taste and excellent nutritional qualities make it an attractive food item.

At least 77 species of tilapia are found in the African continent, but only nine are considered to be suitable for aquaculture. These species differ in a number of important culture traits. For example, *Oreochromis aureus* is the most cold-tolerant (tilapia generally die at temperatures below 50°F) while *O. mossambicus* is tolerant to high salinities.

Aquaculturists have increased the diversity within tilapia genera by crossing species to create hybrids or through programs of selective breeding to develop new strains. Many new strains have resulted from accidental crossing (contamination) of pure species. Strains also develop naturally within a species when there is geological isolation. An example of significance to aquaculture is the occurrence of three distinct species of *O. niloticus*, the Ghana, Ivory Coast and Egypt strains, with varying culture characteristics such as cold tolerance and growth rate.

One major breakthrough in the development of new strains was the appearance of a red mutant *O. mossambicus* in Taiwan in 1968. This single fish was crossed with *O. niloticus* to begin a strain of red tilapia, which led to a second wave of tilapia dispersal to tilapia-culturing countries where the red strain was crossed with other species to create new strains of red tilapia, some containing genes from as many as four species. Selective breeding of red tilapia strains has improved their appearance from an initial mottled look with blotches of dark wild color to a blend of red, orange, pink and white. Red tilapia now resemble colorful ocean fish such as red snapper, which increases their marketability.

Wide variability among cultured tilapia species and strains causes uncertainty during stock selection. Farmers want stock that exhibit fast growth, high survival, efficient feed conversion, attractive coloration and good body conformation under actual culture conditions. Other desirable traits include resistance to disease, high dressing percentage and high quality flesh. To aid perspective Virgin Islands fish farmers in selecting the best available stock, two species comparison experiments were conducted at the University of the Virgin Islands Agricultural Experiment Station (UVI-AES). In experiment 1, the performance of *O. niloticus*, *O. aureus* and three strains of red tilapia were evaluated in freshwater cages. In experiment 2, the performance of *O. mossambicus* and "Florida" red tilapia were evaluated in saltwater cages.

In experiment 1, tilapia stocks came from the following sources:

1) *Oreochromis niloticus* (Ivory Coast strain). The stock of *O. niloticus* originated in West Africa and was shipped to Auburn University via Brazil in 1974. Fish were subsequently shipped from Auburn University to the Tennessee Valley Authority in Muscle Shoals, Alabama, and from there to UVI-AES in 1981.

2) *Oreochromis aureus*. The stock of *O. aureus* originated in Israel from which fish were shipped to Auburn University in 1957. Fish were subsequently shipped from Auburn University to the University of Puerto Rico, Mayaguez, and from there to UVI-AES in 1974.

3) "Florida" red tilapia (FRT). FRT was developed in the late 1970s at Natural Systems in Palmetto, Florida, by crossing wild (black) *O. urolepis*

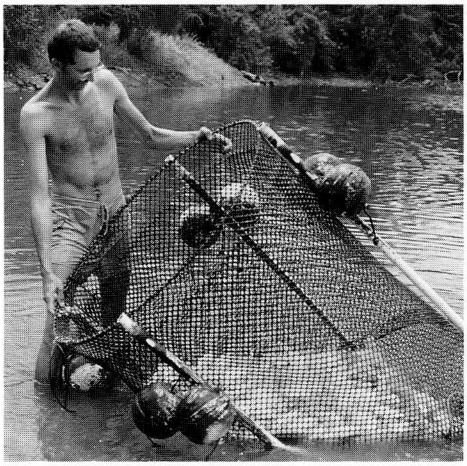
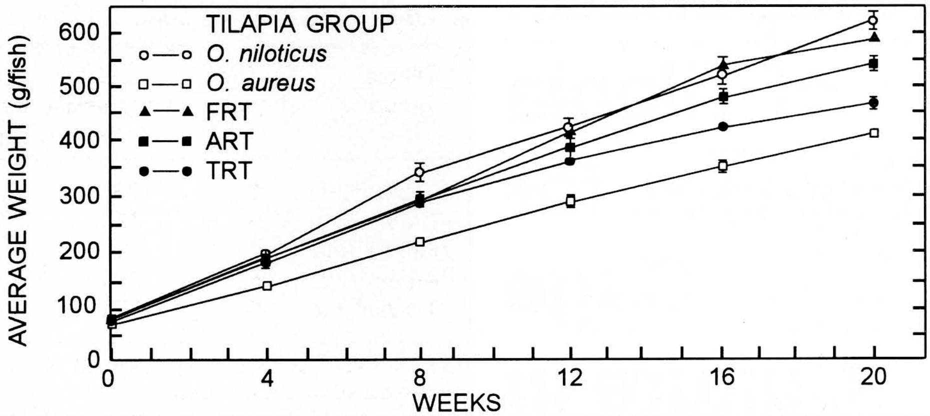


Figure 1. Average growth rate of *O. niloticus*, *O. aureus*, and "Florida," "Aurea" and "Taiwan" red tilapia cultured in 1-m3 cages for 143 days.



hornorum females with red *O. mossambicus* males to produce F_1 (first generation) hybrids exhibiting variable skin coloration ranging from white to red/orange with melanistic (black) mottling. After an extensive selective breeding program, initially at South Florida Fisheries in Lantana, Florida, and later by Sunfish Hatcheries in Jamaica, F_{15} or F_{16} fish were obtained by UVI-AES in 1986 from the Jamaican hatchery and used in experiment 1.

4) "Aurea" red tilapia (ART). Male F_1 "Florida" red hybrids (*O. urolepis hornorum* X *O. mossambicus*) were crossed with female *O. niloticus* and female *O. aureus* in the early 1980s at Tennessee Valley Authority. The red progeny of these crosses were crossed again to form a "four-way line" containing 25% of the genetic material of each of the parent species. South Florida Fisheries crossed wild *O. aureus* females with four-way line males to produce F_2 ART. This process was repeated until an F_4 ART was obtained that consisted of 95% *O. aureus* heritage. UVI-AES received F_4 ART from Sunfish Hatcheries in 1986 and used them in experiment 1.

5) "Taiwan" red tilapia (TRT). This strain was developed in Taiwan from 1968-1972 by crossing red female *O. mossambicus* with male *O. niloticus*. In 1983, the University of Puerto Rico provided UVI-AES with TRT which were derived from a founder stock of 40 fish from Panama.

The freshwater cage culture study was conducted in Chimney Bush pond, a five-acre watershed pond on St. Croix, in 1-m^3 ($35ft^3$) cages. The cages were 3.5 feet in diameter, four feet deep and made from semi-rigid plastic screen with 0.75-inch mesh. The cages were individually anchored to concrete blocks and placed in six rows of five cages each. The rows of cages were perpendicular to the pond bank and roughly parallel with the prevailing wind direction (east, northeast). Cages were placed approximately six feet apart within rows and 20 feet apart between rows.

A demand (self) feeder was secured to the top of each cage. The feeders were checked every day at 10:00 a.m. and 3:00 p.m. and refilled when empty with 12 lb of floating, pelleted feed containing a nutritionally-complete diet (36% protein, Purina #5144).

The fingerlings in this study were fed a male sex hormone as fry to convert the female fry to males. Sex-reversed male fingerlings of each tilapia group were stocked at a rate of 300 fish per cage into six cages. Tilapia groups were assigned to cages according to a randomized complete block design with each row of cages representing a block. Three of the 30 cages were lost during the experiment due to the theft of one cage from each red strain. At intervals of 28 feeding days, approximately 20% of the fish from each cage were weighed, counted and returned to the cage. The experiment was terminated after 143 feeding days, at which time all of the fish were weighed and counted.

During the harvest, ten fish were

selected from each tilapia group and weighed individually to the nearest gram. Scales, gills and viscera were removed from each fish, which was then reweighed to determine dressing percentage with head. After removing the head, the carcass was weighed again to determine dressing percentage without head.

Ten additional fish were selected from each tilapia group and weighed individually to the nearest gram. After scaling the fish, two fillets were excised from each fish and weighed. The fillets were reweighed following removal of the skin. The percentage of the fillet yield with and without skin was calculated.

A gross proximate analysis of body composition was conducted on three individuals of each tilapia group. Moisture was determined by drying the fish in an oven. Crude protein was determined by Kjeldahl-sulfuric acid digestion. Lipid (fat) was determined by the modified Babcock method.

Results of this study showed that *O. niloticus* was the fastest-growing species (3.77g/day) and grew to the largest size (616 g, 1.37 lbs.) within the 20-week culture period (Figure 1, Table 1). Among the red varieties, the "Florida" red tilapia grew at the highest rate (3.50 g/day) to the largest size (577 g, 1.27 lbs.). As cage biomass increased, growth rates declined for TRT after week 8, for *O. aureus* after week 12, and for FRT and ART after week 16 (Figure 1). Although *O. niloticus* grew at its highest rate from week 4 through 8, it continued to grow at a steady and substantial rate through week 20.

Net production reflected the growth rate with *O. niloticus* ranking first and FRT ranking second (Table 2). Total production ranged from 119 kg (262 lbs.)/m^3 (35ft^3) for *O. aureus* to 182 kg (400 lbs.)/m^3 (35ft^3) for *O. niloticus*. There was little difference in total production per cage between FRT (163 kg, 359 lbs.) and ART (161 kg, 354 lbs.). Survival ranged from 93.3% for FRT to 98.4% for *O. aureus*.

The feed conversion ratio (FCR), calculated by dividing feed weight by fish weight gain, ranged from 1.29 for *O. aureus* to 1.68 for TRT (Table 2). This

Table 1. Average initial and final body weight, daily weight gain and specific growth rate of *O. niloticus*, *O. aureus* and "Florida," "Aurea," and "Taiwan" red tilapia cultured in 1.0-m^3 cages for 143 days.

Tilapia group	Number of cages	Initial body weight (g/fish)	Final body weight (g/fish)	Daily weight gain (g)	Specific growth rate (%/day)
O. niloticus	6	73c[1]	616a[2]	3.77a[2]	1.45a[2]
O. aureus	6	77b	403d	2.28d	1.16d
"Florida" red	5	70d	577b	3.50b	1.41ab
"Aurea" red	5	83a	551b	3.31b	1.38b
"Taiwan" red	5	85a	470c	2.75c	1.27c

[1]Average values within a column followed by the same letter are not significantly different (P>0.05) as determined by pairwise t-tests.
[2]These average values are "least square means," the values that would have occurred if the initial body weights were equal.

Table 2. Average initial and final fish biomass, net production, feed conversion ratio and survival rate of *O. niloticus*, *O. aureus* and "Florida," "Aurea," and "Taiwan" red tilapia cultured in 1.0-m^3 cages for 143 days.

Tilapia group	Number of cages	Initial biomass (kg/m3)	Final biomass (kg/m3)	Net production (kg/m3)	Feed conversion ratio	Survival rate (%)
O. niloticus	6	22c[1]	182a[2]	159a[2]	1.30c[2]	97.7a[2,3]
O. aureus	6	23b	119c	96c	1.29c	98.4a
"Florida" red	5	21d	163b	140b	1.45b	93.3b
"Aurea" red	5	25a	161b	138b	1.31bc	98.3a
"Taiwan" red	5	25a	132c	109c	1.68a	94.9ab

[1]Average values within a column followed by the same letter are not significantly different (P>0.05) as determined by pairwise t-tests.
[2]These average values are "least square means," the values that would have occurred if the initial body weights were equal.
[3]Survival growth rates were arcsine-transformed prior to analysis.

Table 3. Average condition factor (K) and dressing percentage of *O. niloticus*, *O. aureus* and "Florida," "Aurea," and "Taiwan" red tilapia[1].

Tilapia group	K[2]	Dressed with head (%)	Dressed without head (%)	Fillet with skin (%)	Fillet without skin (%)
O. niloticus	3.11b[3]	85.6a[4]	65.6a[4]	39.0a[4]	33.4a[4]
O. aureus	3.00c	85.2a	64.7a	38.4a	33.8a
"Florida" red	3.21a	84.9a	64.0bc	38.6ab	34.3a
"Aurea" red	2.87d	85.6a	64.3ab	38.3a	33.5a
"Taiwan" red	2.85d	86.0a	63.4c	36.4b	31.1b

[1] Ten individuals were analyzed from each group for dressing percentage with and without head; ten individuals were analyzed from each group for dressing percentage of fillet with and without skin.
[2]K = body weight (g) x 10^5/total length (mm)^3.
[3]Average values within a column followed by the same letter are not significantly different (P>0.05) as determined by pairwise t-tests.
[4]These average values are "least square means," the values that would have occurred if the initial body weights were equal to 456g for dressed with and without head and 571g for fillet with and without skin. All percentage data was arcsine-transformed prior to analysis.

Table 4. Average moisture, protein and lipid content of *O. niloticus*, *O. aureus* and "Florida," "Aurea," and "Taiwan" red tilapia[1].

Tilapia group	Moisture (%)	Protein (%)	Lipid (%)
O. niloticus	78.2a[2]	18.5cd	1.4b
O. aureus	75.3c	21.0a	1.4b
"Florida" red	76.4bc	20.1b	3.6a
"Aurea" red	78.0ab	17.7d	1.2b
"Taiwan" red	78.5a	19.1c	1.2b

[1]Three individuals were analyzed from each group.
[2]Average values within a column followed by the same letter are not significantly different (P>0.05) as determined by pairwise t-tests.

means that 1.29 lb of feed were required to produce a one-pound weight gain in *O. niloticus* compared to 1.68 lb of feed for a one-pound gain in TRT. The FCR values of *O. niloticus* (1.30) and ART (1.31) were exceptionally low for such large fish. The use of demand feeders appears to be a very efficient method of feeding caged tilapia.The FCR of FRT was numerically intermediate (1.45).

The condition factor is a number that relates weight to length and indicates how robust (or emaciated) a fish is. FRT displayed the highest (best) condition factor (3.21), followed by *O. niloticus* (3.11) (Table 3). The lowest condition factors occurred among TRT (2.85) and ART (2.87). These strains were visibly thinner than the other tilapia groups, and approximately 15% of TRT exhibited some degree of caudal fin rot.

The dressing percentage with head (scales, gills and viscera removed) was similar for all the tilapia groups, ranging from 84.9% for FRT to 86.0% for TRT (Table 3). With the removal of the head, some statistically significant changes occurred in the ranking. TRT displayed the lowest dressing percentage (63.4%), indicating that its head size was relatively large compared to its body, while *O. niloticus* exhibited the highest dressing percentage (65.6%), suggesting that its head size was relatively small. Small head size is a desirable trait because meat yield increases as head size decreases. This relationship was confirmed by the results of fillet yield with skin, which was lowest for TRT (36.4%) and highest for *O. niloticus* (39.0%). With the removal of skin, *O. niloticus* dropped to fourth in the ranking of fillet yield (33.4%), indicating that its skin may be thicker than the skin of the other tilapia groups. The fillet skin ranged from 4.3% (FRT) to 5.6% (*O. niloticus*) of total body weight. The differences in dressing percentages among the tilapia groups were relatively minor except for those of TRT, which were significantly lower in most categories.

Gross proximate analysis of body composition revealed that from 75.3% (*O. aureus*) to 78.5% (TRT) of total body weight consisted of moisture (Table 4). Protein levels ranged from 17.7% (ART) to 21.0% (*O. aureus*). Lipid content, which was similar among four of the groups (1.2-1.4%), was significantly higher (3.6%) for FRT. Fat deposits were visible in the flesh of FRT and in a thick layer over the swim bladder. FRT registered the highest condition factor (Table 3), another indication that it was the fattest fish. FRT may require a restricted feeding regime or a diet with a lower energy-to-protein ratio to reduce fat content. The most nutritious species was *O. aureus*, which registered the lowest moisture content, the highest protein level and a moderate lipid level.

By nearly all measures, the culture performance of *O. niloticus* was superior to the other tilapia groups. Dressing characteristics of *O. niloticus* were similar to or better than the other groups, although protein levels were comparatively low. If color is not a factor in marketing tilapia products, such as skinless fillets, *O. niloticus* is the best species for freshwater cage culture in the Virgin Islands. After completing this study, UVI-AES replaced the Ivory Coast strain of *O. niloticus* with the Egypt strain, which grows faster according to a recent study. The other pure species in this study, *O. aureus*, grew at a low rate and should not be considered for culture, although all other growth and dressing characteristics were favorable.

Marketing studies have shown that Virgin Islanders prefer red tilapia because they resemble brightly-colored ocean fish. Among the red strains, FRT performed best in most categories, except survival, feed conversion and fat content. ART performed nearly was well as FRT, and most of the differences between ART and FRT were not statistically significant. However, production of F_4 ART fingerlings involves the maintenance of separate breeding lines and is much more complicated than using a single FRT strain to generate seed stock. Since ART offers no clear growth or dressout advantage, FRT is the recommended strain of red tilapia for the Virgin Islands. TRT performed poorly in growth, feed conversion and meat yield and is therefore unsuitable for the Virgin Islands.

In experiment 2, *O. mossambicus* were derived from stocks captured in the Salton Sea in California and transported to the University of Puerto Rico and from there to UVI-AES in 1988. FRT came from the same source as described in experiment 1.

The study was conducted on St. Croix in Salt River Bay, a protected embayment which is open to the sea and receives freshwater runoff only during periods of intense rainfall. During the study, salinity ranged from 35 to 38 parts per thousand (ppt).

Three cross-shaped rafts (wooden walkways) were anchored in approximately nine feet of water at a distance of 30 feet from a fringe of red mangrove in a small arm of the bay. Two 2-m^3 (70ft^3) cages were secured to each of the three rafts. The cages were constructed of galvanized mesh (0.75-inch) formed into a rectangular shape measuring five feet long by four feet wide by four feet deep. The mesh was treated with a blue antifouling paint containing tributyltin fluoride.

A feeding ring was placed in each cage. Initially, 0.12-inch plastic mesh was tied to rubber inner tubes. Many inner tubes deflated due to degradation of the rubber by salt water and sunlight. These were replaced by encapsulated polystyrene rings measuring 16 inches (inner diameter) by 24 inches (outer diameter) by six inches (height). The same 0.12-inch plastic mesh was tied to the outside of the rings and extended 12 inches into the water.

Sex-reversed male fingerlings of each tilapia group were stocked at a rate of 40 fish per cage (20 fish/m^3, 35ft^3) into three cages, one cage from each raft. The cages were stocked at low rates due to a shortage of fingerlings and the logistics of acclimating the fingerlings to seawater. The fingerlings had been raised in fresh water and were acclimated to seawater over a five-day period by direct transfer to aerated tanks of increasing salinity: 15 ppt (day 1), 20 ppt (day 2), 25 ppt (day 3), 30 ppt (day 4), and 35 ppt (day 5).

The fish were fed a floating, nutritionally complete diet (36% protein, Purina #5144) at 3.0% of body weight daily once per day in the morning. The feeding rate was adjusted weekly based on an assumed feed conversion ratio of 2. The fish were not sampled during the experiment to avoid injury and subsequent infection, as tilapia are not as resistant to disease in full-strength seawater as they are in fresh water. After 50 feeding days, the fish began to show signs of bacterial infection which led to low rates of mortality. After 64 days, feed treated with oxytetracycline (Terramycin) was offered to the fish at a rate of 80 mg/kg of fish body weight for 14 days. Fish resumed active feeding following treatment with medicated feed, although feed quantity was restricted to that which could be consumed within a short period. The experiment was terminated after 112 feeding days, at which time all of the fish from each cage were weighed and counted.

The culture performance of FRT was superior to that of *O. mossambicus*, indicating that FRT is more suitable for culture in marine cages (Table 5). FRT grew at a faster rate (2.56g/day) and reached a larger size (439 g, 0.97 lbs.) than *O. mossambicus* (2.08 g/day and 381 g, 0.84 lbs.) Final cage biomass and survival were higher for FRT (16.6 kg, 36.6 lbs. and 94.2%) than *O. mossambicus* (13.0 kg, 28.6 lbs. and 83.3%). The feed conversion ratio was lower for FRT (2.52) than for *O. mossambicus* (3.56).

The superior performance of FRT was probably due to its heritage from two saltwater-tolerant species (*O. urolepis hornorum* and *O. mossambicus*) and to a 10-year selective breeding program for improved growth and color, whereas *O. mossambicus* originated from an unselected (wild) population. FRT grew at a slower rate in saltwater cages (2.56 g/day) than it did in freshwater cages (3.61 g/day), but this may have resulted from the different feeding regimes (once a day feeding in salt water compared to continuous feeding in fresh water). The bay was too rough for demand feeders.

Table 5. Mean ± standard error of initial and final body weight, specific growth rate, weight gain, final cage biomass and survival rate of "Florida" red tilapia and *O. mossambicus* cultured in 2-m^3 cages for 112 days in seawater.

	"Florida" red	*O. mossambicus*
Initial body weight (g)	152 ± 3	148 ± 4
Final body weight (g)	439 ± 2	381 ± 21
Specific growth rate (%/day)	0.95 ± 0.01	0.84 ± 0.04
Weight gain (g/day)	2.56 ± 0.01	2.08 ± 0.17
Final cage biomass (kg/m^3)	8.3 ± 0.3	6.5 ± 1.5
Survival rate (%)	94.2 ± 3.0	83.3 ± 16.7

The underlying cause of the bacterial disease episode may have been poor nutrition. In an effort to obtain maximum growth rates, the fish were initially fed at a rate beyond satiation, contributing to the high feed conversion ratios. Large quantities of feed remained on the surface for several hours and became saturated with seawater, possibly leaching water-soluble nutrients. Ingestion of this water-soaked feed of reduced nutritional quality may have stressed the fish to the extent that their resistance to marine pathogens was weakened. Upon completion of the antibiotic treatment, the fish remained free of diseases at feeding rates that allowed them to consume the feed quickly.

Based on these studies, in the Virgin Islands *O. niloticus* and "Florida" red tilapia are recommended for freshwater cage culture and "Florida" red tilapia is recommended for saltwater cage culture. Tilapia farmers should be aware that there are other species, strains and crosses that have not been tested here, and that tilapia breeding programs throughout the world are continually striving to improve growth characteristics. New breeds should periodically be tested under Virgin Islands conditions. Furthermore, individual farmers must establish their own breeding programs to prevent inbreeding and maintain the quality of their stocks.

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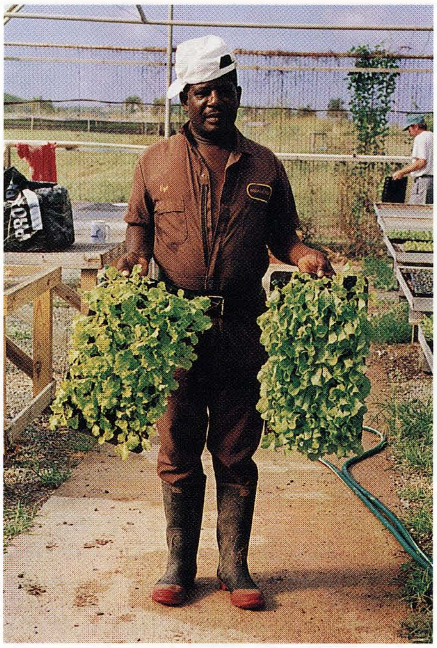

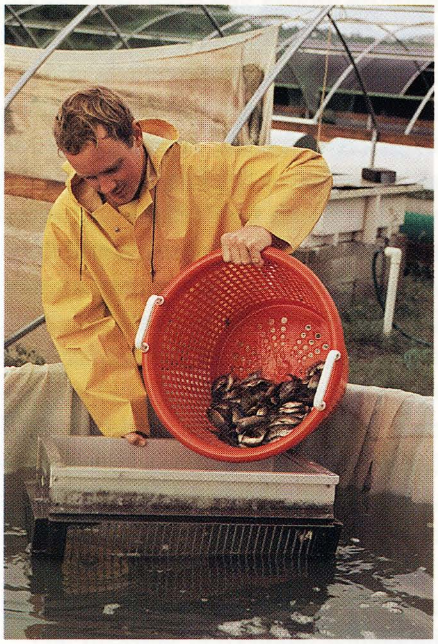

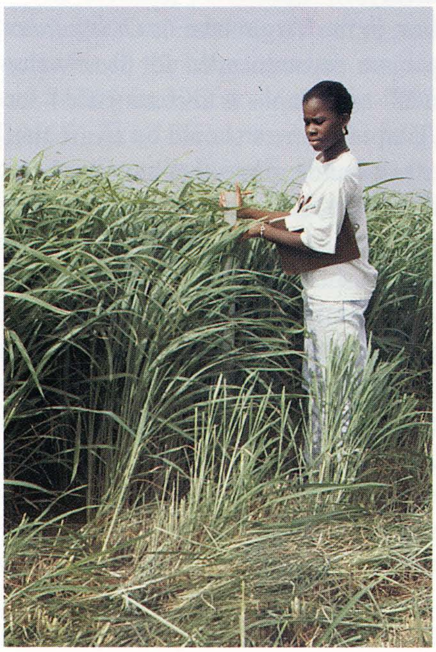

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Current Research Projects

Evaluation of Forage Conservation Systems in the Caribbean.
Evaluation of Integrated Mechanical and Chemical Control of Casha (*Acacia* spp.) on Native Pasture.
Improving Forage Feeding Value by Urea Treatment.
Breeding and Biotechnology for Forage Yield, Quality and Persistence of *Pennistems*.
Evaluation of Native Pasture and Agro-By-Product-Based Systems for Market Lamb Production.
Herbage Allowance and Pasture Rotation Systems for Animal and Forage Production on Tropical Pasture.
Increased Efficiency of Sheep Production.
Reducing Effects of Heat Stress on Reproduction in Dairy Cattle.
Evaluation of Tropical Adaptation of Non-Zebu Cattle Germplasm.
Studies on the Production of Tilapia in Marine Cages.
Evaluation of the Culture Potential of Selected Caribbean Marine Finfish.
Integration of Tilapia and Hydroponic Vegetable Production in Recirculating Systems.
Economic Analysis of Integrated Recirculating Systems.
Integrating Tilapia Culture in Tanks with Field Production of Vegetable Crops.
Micro-Irrigation of Horticultural Crops in Humid Regions.
Evaluation of Saline Water for Irrigating Vegetable Crops in the U.S. Virgin Islands.
Horticultural and Economic Evaluation of Vegetable Varieties in the U.S. Virgin Islands.
Alley Cropping Systems for Sustainable Vegetable Production in the U.S. Virgin Islands.
Improving Crop Management Systems for the Production of Culinary Herbs in the U.S. Virgin Islands.
Evaluation of Horticultural Practices for Enhancing Root Crop Production in the Virgin Islands.
Evaluation of Cultural Practices for Sweet Potato Weevil Control.
Evaluation of Integrated Production Methods for Tropical Fruit Crops.
Evaluation of the Effects of Tissue Culture on Somatic Variation and Propagation of Breadfruit.
Evaluation of Minor Tropical and Subtropical Fruits and Nuts for Production in the U.S. Virgin Islands.
Evaluation of Trees for Agroforestry in the U.S. Virgin Islands.
Potential for Ornamental Pot Crops in the Virgin Islands Using Growth Regulators.
Transformation and Regeneration of Hibiscus and Bougainvillea.
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*An asterisk in front of an entry indicates that it has been previously listed, but was in press before. Now the entry is complete.

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